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NIAGARA RIVER MUSSEL BIOMONITORING PROGRAM

1995

NOVEMBER 1997

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Ministry
of the
Environment

NIAGARA RIVER MUSSEL BIOMONITORING PROGRAM, 1995

Lisa A. Richman
Surface Water Section
Environmental Monitoring and Reporting Branch

1997

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FOREWORD

The data generated by the 1995 Niagara River Biomonitoring Survey augment other federal and provincial Niagara River Toxics Management Plan programs by providing information on contaminants in the river between Fort Erie and Niagara-on-the-Lake. The Niagara River mussel biomonitoring survey, as conducted biennially by the Ontario Ministry of Environment, has been ongoing since 1980 (Kauss 1987; Kauss and Angelow 1988; Anderson *et al* 1991; Richman 1992; Richman 1993; Richman 1994).

Information provided by this study is part of an overall program to assess long-term trends in contaminant loadings from selected sources along the Niagara River.

ACKNOWLEDGEMENTS

The 1995 Niagara River Biomonitoring study was conducted by the Surface Water Section of the Environmental Monitoring and Reporting Branch of the Ontario Ministry of Environment (OMOE).

The author expresses appreciation to: Jörgen Fleischer, Duncan Boyd, Peter Kauss and Alan Hayton of the Environmental Monitoring and Reporting Branch and to Wally Rozenberg of West Central Region for their constructive reviews of the report, and to Keith Somers (Standards Development Branch) for statistical advice.

The author would also like to acknowledge the efforts of the crew chief Greg Hobson and summer student Heather Young for the field work. The author further acknowledges the efforts of the Biomaterials and Sediment Unit and Dioxin and Furan Unit of the OMOE Laboratory Services Branch for the analysis of these samples.

The map of the Niagara River used in Figure 1 was provided by Environment Canada. The author expresses appreciation to Susan Holland-Hibbert for her assistance and transmission of the map files. The Canadian portion of the shoreline was digitized by Geomatics International in 1992 as part of the International Joint Commission Water Levels Reference Study. The U.S. shoreline was digitized by Environment Canada from NOAA Hydrographic maps in 1993. Major and minor rivers were obtained from the Ecosystem Health Division of Environment Canada.

The author would like to express appreciation to Robert Bilyea of the Environmental Monitoring and Reporting Branch (OMOE) for his assistance with the customization of the map in Figure 1 to accommodate the Niagara River survey.

SUMMARY

Background

Since 1980 the Ontario Ministry of Environment (OMOE) has been committed to both routine and specialized biomonitoring of contaminants in the Niagara River using caged mussels (*Elliptio complanata*). The cooperative assistance of the New York State Department of Environmental Conservation (NYSDEC) has enabled the OMOE to deploy mussels on the U.S. as well as the Canadian side of the river. These studies have provided information on suspected contaminant sources and source areas and the effectiveness of site remediations in reducing contaminants in the river between Fort Erie and Niagara-on-the-Lake (Kauss 1987; Kauss and Angelow 1988; Anderson *et al* 1991; Richman 1992; Richman 1993; Richman 1994).

In 1995, two complementary studies were initiated by the OMOE:(a) the routine deployment of caged mussels at 22 stations on the Canadian and U.S. sides of the river for 21 days of exposure, and (b) a long term deployment up to four months at two stations. Mussels were retrieved after the designated period of deployment and the tissues were analysed for organochlorine pesticides, total polychlorinated biphenyls (PCBs), chlorinated benzenes, polycyclic aromatic hydrocarbons (PAH) and polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/PCDF).

Twenty-one day exposure findings

Analytical results from the caged mussel study were similar to those in previous years of monitoring since 1980. Organochlorine pesticides, chlorinated benzene compounds and PCBs were not detected in mussels introduced on the Canadian side of the river, with the exception of trace concentrations of p,p'-DDE and p,p'-DDD (metabolites of the pesticide DDT), and one mussel deployed at Millers Creek where trace concentrations of hexachlorobenzene were detected.

Typical of previous mussel surveys, organochlorine pesticides and PCBs were detected sporadically at several stations while chlorinated benzene compounds were detected at all stations on the U.S. side of the river.

Hexachlorocyclohexane (α-BHC and β-BHC) was detected in mussels at five sites on the U.S. side of the river including the site at the 102nd Street Landfill where BHC has been routinely detected since 1987. Trace concentrations of γ-BHC and α and γ-chlordane were detected in mussels at two stations.

PCBs were present in mussels deployed downstream of the 102nd Street Landfill (NY), adjacent to sewers associated with Occidental Chemical Corporation, in Cayuga Creek and in mussels placed in Gill Creek north of highway 384. The Gill Creek site was upstream of the area previously remediated for PCBs. High concentrations of PCBs in mussels at this site suggest either a present and/or historical source(s) of PCBs to this portion of the creek. Plans for remediation are in progress.

The most frequently detected chlorinated benzenes were; hexachlorobenzene which was detected at all but one station, pentachlorobenzene which was present at all but two stations and 1,2,3,4-tetrachlorobenzene which was detected at ten out of 16 stations. The highest concentrations of chlorinated benzenes were in mussels deployed at the 102nd Street Landfill and at stations associated with the Occidental Chemical Corporation. These results are consistent with previous OMOE mussel biomonitoring surveys. Concentrations of chlorinated benzenes typically found in caged mussels at the Pettit Flume (NY) in past OMOE surveys were lower in 1995 than concentrations found in previous years and likely reflect the success of the past remedial actions by the Occidental Chemical Corporation.

Consistent with previous studies, high concentrations of some PAH compounds were present in mussels at the mouth of Two Mile Creek. High PAH concentrations were also detected in mussels deployed in Cayuga Creek.

Bloody Run Creek and the nearby seepages which run down the face of the Niagara Gorge were historically contaminated from the Hyde Park landfill. Prior to site remediation, the drainage from the Hyde Park landfill was a major source of dioxin contamination to the Niagara River (Gradient Corporation 1990). Remediation of the landfill and Bloody Run Creek was completed by the Occidental Chemical Corporation in 1994. Dioxin and furan mussel tissue concentrations in this study were considerably lower than concentrations reported in 1993. Isomer patterns in mussel tissue were consistent with previous surveys with 100% of the tetrachlorodibenzo-p-dioxin (T4CDD) detected as 2,3,7,8-T4CDD at high concentrations (120 pg/g). Concentrations of 2,3,7,8-T4CDF were low (6 pg/g) and only 12% of the total congener group. The presence of other toxic isomers in mussel tissue were low relative to mussels placed at the 102nd Street Landfill site showing distinct isomer patterns for the two monitoring sites. Although concentrations in mussels were lower than previously measured, this site will be monitored in future surveys since the contaminated sediment covered during the remediation along the Niagara River shoreline and at the mouth of the creek may continue to be a source. Water levels fluctuate daily to maintain the operation of the hydro generating stations thereby routinely submerging and then exposing the contaminated shoreline.

Summary of organochlorine pesticides, PCBs, industrial compounds and chlorinated benzene contaminants in caged mussel tissue from the 21 day exposure to the Niagara River.

Canadian Sites	*Contaminant*
Fort Erie at Robertson Street	
Frenchmans Creek (mouth)	pp'-DDD$_{(t)}$, pp'-DDE$_{(t)}$
Millers Creek (mouth)	pp'-DDE$_{(t)}$, HCB$_{(t)}$
Chippawa Channel	
Niagara-on-the-Lake	pp'-DDE$_{(t)}$
US Sites	
Buffalo River	α-BHC, β-BHC, α-chlordane$_{(t)}$, γ-chlordane$_{(t)}$, HCB$_{(t)}$, pentachlorobenzene, 1,2,3-trichlorobenzene$_{(t)}$, 1,2,4-trichlorobenzene$_{(t)}$
Black Rock Canal	pp'-DDE$_{(t)}$, hexachloroethane, pentachlorobenzene$_{(t)}$, 2,4,5-trichlorotoluene
Tonawanda Channel (upstream of Two Mile Ck)	α-BHC, β-BHC$_{(t)}$, γ-BHC$_{(t)}$, PCBs, pp'-DDE$_{(t)}$, HCB, pentachlorobenzene, 1,2,3-trichlorobenzene$_{(t)}$, 1,2,4-trichlorobenzene, 1,3,5-trichlorobenzene, 1,2,3,4-tetrachlorobenzene, 1,2,3,5-tetrachlorobenzene, 1,2,4,5-tetrachlorobenzene
Two Mile Creek (mouth)	pp'-DDE$_{(t)}$, HCB$_{(t)}$, pentachlorobenzene$_{(t)}$, 1,2,3,4-tetrachlorobenzene $_{(t)}$
Pettit Flume (site B)	pp'-DDE$_{(t)}$, HCB, pentachlorobenzene, 1,2,3,4-tetrachlorobenzene, 1,2,3,5-tetrachlorobenzene, 1,2,4,5-tetrachlorobenzene
Gratwick/Riverside Park	pp'-DDE$_{(t)}$, HCB, pentachlorobenzene, octachlorostyrene, 1,2,3,4-tetrachlorobenzene, 1,2,3,5-tetrachlorobenzene$_{(t)}$, 1,2,4,5-tetrachlorobenzene $_{(t)}$
Wheatfield	pp'-DDE$_{(t)}$, HCB$_{(t)}$, pentachlorobenzene$_{(t)}$.
102nd Street Landfill (upstream)	pp'-DDE$_{(t)}$, HCB$_{(t)}$, pentachlorobenzene$_{(t)}$

Summary continued	*Contaminant*
102nd Street Landfill	α-BHC, β-BHC$_{(t)}$, γ-BHC$_{(t)}$, PCBs, pp'-DDE$_{(t)}$, HCB, pentachlorobenzene, octachlorostyrene$_{(t)}$, 2,4,5-trichlorotoluene, 1,2,3-trichlorobenzene$_{(t)}$, 1,2,4-trichlorobenzene, 1,3,5-trichlorobenzene$_{(t)}$, 1,2,3,4-tetrachlorobenzene, 1,2,3,5-tetrachlorobenzene, 1,2,4,5-tetrachlorobenzene
Cayuga Creek	α-BHC, β-BHC, γ-BHC$_{(t)}$, α-chlordane$_{(t)}$, γ-chlordane$_{(t)}$, PCBs, pp'-DDD$_{(t)}$, HCB$_{(t)}$, hexachloroethane, pentachlorobenzene, 2,4,5-trichlorotoluene$_{(t)}$, 1,2,3,4-tetrachlorobenzene
Occidental - Sewer C (upstream of Sewer 003)	α-BHC, β-BHC, PCBs, pp'-DDE, HCB, pentachlorobenzene, octachlorostyrene, 2,4,5-trichlorotoluene$_{(t)}$, 1,2,3,4-tetrachlorobenzene
Occidental Sewer 003	HCB, pentachlorobenzene, 2,3,6-trichlorotoluene, 2,4,5-trichlorotoluene, 1,2,3,4-tetrachlorobenzene
Occidental - Storm Sewer	HCB, pentachlorobenzene, 1,2,3,4-tetrachlorobenzene 2,3,6-trichlorotoluene$_{(t)}$, 2,4,5-trichlorotoluene$_{(t)}$,
Occidental Sewer 002	PCBs, pp'-DDE$_{(t)}$, HCB, pentachlorobenzene 1,2,3,4-tetrachlorobenzene, octachlorostyrene$_{(t)}$
Gill Creek (upstream)	PCBs, HCB$_{(t)}$, hexachloroethane, octachlorostyrene$_{(t)}$
Bloody Run Creek	HCB, pentachlorobenzene, octachlorostyrene$_{(t)}$
$_{(t)}$ - Trace concentrations, interpret with caution	

Long Term Deployment Findings

Mussels were placed at the 102nd Street Landfill and the Occidental Sewer 003 for long-term deployment experiments (up to 18 weeks). Contaminants were bioaccumulated within the first 24 hours of exposure at both locations. The unique pattern of contaminant uptake at each station, the difference in tissue concentrations of 1,2,3,4-tetrachlorobenzene, pentachlorobenzene and hexachlorobenzene in mussels at the two sites (concentrations of chlorobenzenes were at times 10 to 100 times higher in mussels at 102nd Street than mussels at Occidental 003), as well as the presence of 2,4,5 and 2,3,6-trichlorotoluene only in mussels deployed at the Occidental Sewer, strongly suggests that the mussels were monitoring contaminant sources specific to each location and confirm that caged mussels are useful as site specific monitors of local near shore water quality.

A plot of rainfall data for the Niagara Falls area (Environment Canada 1995) with mussel deployment/retrieval times suggests that contaminant uptake patterns in mussels at the 102nd Street Landfill may reflect contaminant inputs from the landfill or possibly other local non point sources in response to rain events. The contaminant uptake pattern in mussels at the 003 outfall did not follow the pattern of rainfall events and was more consistent with an intermittent industrial point source discharge.

The fluctuations in tissue contaminant concentrations suggest that the water quality of the local sites was not constant. Although site specific water quality data were not collected for these sites as part of this study, data from the Environment Canada Upstream/Downstream water quality monitoring program for July 1995 to December 1995 showed large fluctuations in weekly loadings of chlorinated benzenes to the Niagara River in water and suspended sediments (K. Kuntz 1997, personal communication). These fluctuations represent the dynamic nature of the many sources of these contaminants to the Niagara River.

Conclusions and Recommendations

The current design of the mussel biomonitoring program (21 day exposure) is useful for identifying contaminant source areas by providing information on the site specific presence and absence of contaminants in the tissue of deployed mussels. There are two recommendations concerning the design of the current survey.

1. Given the large within-station variability in mussel contaminant concentrations, future Niagara River Biomonitoring Study designs should consider the option of a single three mussel composite sample analysis per station rather than analysing three individual mussels.

2. The data collected provides qualitative information on the long term (i.e. data collected over the past 15 years) presence/absence of contaminants at individual stations. This study could still fulfill its objectives if it is carried out every three years rather than the present schedule of every two years. This new monitoring schedule would be consistent with other ongoing OMOE Great Lakes monitoring activities within the Environmental Monitoring and Reporting Branch.

In addition, the objective of future biomonitoring studies should be reviewed.

The long term deployment study using caged mussels produced results which suggest that there are fluctuating inputs of contaminants from non-point sources, and these inputs may be directly related to rain events. This theory is not new and has always been suspected of many non-point sources, however, there is a lack of information on temporal changes in pollution inputs from non point sources within the Niagara River and there is little information on the bioavailability of the contaminants, particularly from hazardous waste sites. This possible linkage of rainfall events with contaminant pulses suggests that the sampling designs using mussels in the future should be flexible to capture these contaminant inputs. The mussels accumulated most contaminants within 24 hours of exposure. Pulse events that occur any time after could be monitored to provide important information on temporal patterns of contaminant inputs.

A limitation of the current objective of the caged mussel study is the inability to use the data to calculate contaminant loadings or long term contaminant discharge patterns; therefore, consideration should be given to including a survey with the objective of investigating contaminant discharge patterns. Since frequent event specific sampling would be required, such a survey should focus on a few priority non-point sources.

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INTRODUCTION

Background

The Niagara River flows from Lake Erie to Lake Ontario at an average flow of 5700 m^3/s (Niagara River Toxics Committee (NRTC) 1984). It is about 64 km long and provides drinking water, power generation, municipal and industrial water supplies and recreation and tourism opportunities to a population of more than one million Canadian and U.S. people. It is also habitat for a diverse fish and wildlife community, however, the integrity of this system is severely impacted due to the discharge of persistent bioaccumulative and toxic chemicals from outfalls and hazardous waste landfills (Elder *et al.* 1981; Kuntz and Warry 1983; Jaffe and Hites 1984; NRTC 1984; Gradient Corp./Geotrans Inc. 1988; Monenco 1991; Raven 1991). The contaminants that were historically discharged, and which (in some cases) are still released from outfalls and inactive hazardous waste sites include chemicals such as mirex, PCBs (polychlorinated biphenyls), organochlorine pesticides such as BHC (lindane), chlorinated benzenes, chlorinated phenols, polycyclic aromatic hydrocarbons (PAH), and polychlorinated dibenzo-p-dioxins and polychlorinated Dibenzofurans (Interagency Task Force on Hazardous Waste 1979; Elder *et al.* 1981; Jaffe and Hites 1984; NRTC 1984; US EPA and NYSDEC 1993, Niagara River Data Interpretation Group, 1996).

Since 1980 the Ontario Ministry of Environment (OMOE) has been committed to routine and specialized biomonitoring of contaminants in the Niagara River using caged mussels (*Elliptio complanata*). The cooperative assistance of the New York State Department of Environmental Conservation (NYSDEC) has enabled the OMOE to deploy mussels on the U.S. as well as the Canadian side of the river. These studies have provided information on suspected contaminant sources and source areas and the effectiveness of site remediation in reducing contaminants in the river between Fort Erie and Niagara-on-the-Lake (Kauss 1987; Kauss and Angelow 1988; Anderson *et al* 1991; Richman 1992; Richman 1993; Richman 1994).

The principle behind this biomonitoring program is to take clean organisms such as mussels (and in some cases leeches) and place them in an environment that is known or suspected of being contaminated with persistent bioaccumulative substances. The biomonitors are left for a specified time to accumulate contaminants and are then analysed to determine the contaminant concentrations in their tissue. By strategically locating the organisms upstream and downstream from a source, or before and after a remedial activity, the presence or absence of the contaminants in the water body, or benefit of the remediation, can be determined. Biomonitors are an effective means of detecting bioaccumulative contaminants in the water when ambient concentrations are too low to be measured directly using conventional water sampling and analytical methods.

The freshwater mussel, *Elliptio complanata*, is a filter feeder, feeding on plankton and organic detritus and will, therefore, accumulate contaminants directly from the water column and from particulate matter (Pennak 1978). This method of feeding renders the mussel a good biomonitor since contaminants tend to partition between the dissolved phase and the solid phase where they become associated with sediment or suspended particulates through adsorptive processes. Mussels are abundant and easily collected and transported. They are sedentary organisms and responsive to their environment. Mussels can integrate short term fluctuations in contaminant levels and, accordingly, tissue concentrations reflect short term contaminant pulses which may not be detected by routine water quality monitoring (Muncaster *et al.* 1989; Metcalfe and Charlton 1990; Kauss and Hamdy 1991; Lobel *et al.* 1991). Conversely, because the sampling design is limited to a particular deployment period, results only reflect the exposure during that period. The results obtained at any one sampling event represent the current contamination integrated by that specific organism and cannot be extrapolated to yearly loadings from sources. Likewise, significant contaminant inputs could be missed if they occur outside the designated period of biomonitoring.

Objectives

The general objective of the mussel biomonitoring program is to monitor the distribution of contaminants in the Niagara River and identify areas of concern for point and non point source investigations.

More specific objectives of this survey were to investigate:

- *How tissue contaminant concentrations of caged mussels deployed in the Niagara River for 21 days varied spatially between the stations?*
- *The qualitative temporal patterns associated with the presence/absence of contaminants (i.e. are specific contaminants consistently detected at specific locations over time?).*
- *The variability in contaminant uptake patterns in caged mussels deployed at two stations over a long term (4 month) exposure.*
- *How caged mussels compared with ongoing long-term trace contaminant monitoring with indigenous species i.e. spottail shiners?*

This report presents the results of the 1995 mussel biomonitoring survey.

METHODS

Field Sampling and Station Locations

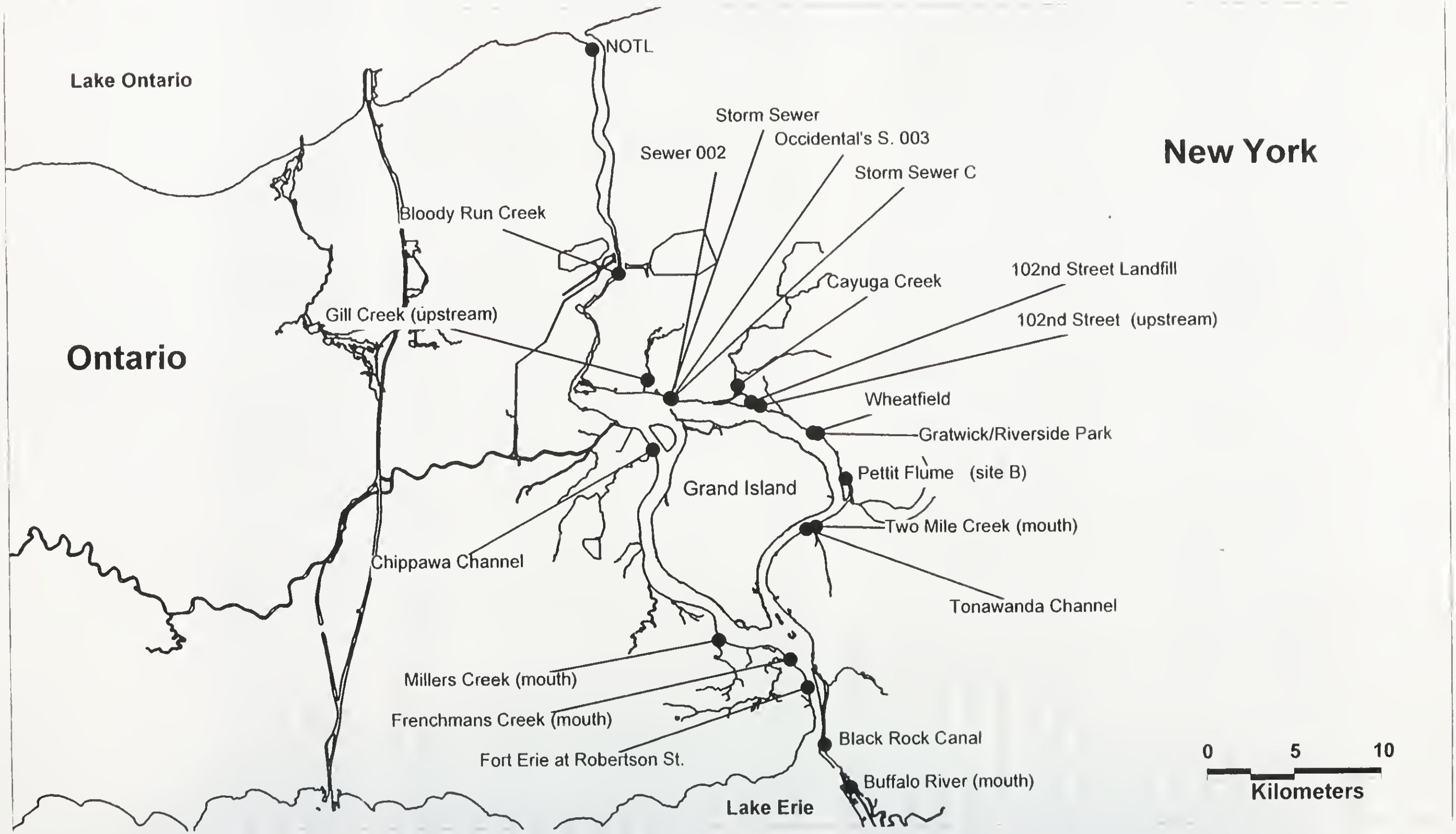
In 1995, there were two studies initiated by the OMOE; the routine deployment of caged mussels at near shore stations on the Canadian and U.S. sides of the river for 21 days of exposure, and long term deployments for up to four months at two stations.

The mussels used for the study originated from Balsam Lake (a relatively uncontaminated lake located in Victoria County, Ontario). Only mussels between 6.5 and 7.2 cm were collected to reduce variability due to tissue weight and mussel age. The mussels were collected by divers and placed in buckets lined with clean bioassay (food-grade) polyethylene bags partially filled with lake water for transportation. The bags were sealed with air trapped inside and rapid temperature fluctuations were avoided. Three random replicate samples of these mussels were submitted for tissue analysis to determine initial concentrations of contaminants. These mussels are referred to as the Balsam Lake control mussels in this report.

Mussels were placed in the Niagara River at 22 sampling stations during the week of July 10, 1995 and retrieved after three weeks of exposure during the week of August 1, 1995. At each station at least six mussels were placed in 30 x 45 cm envelope-shaped cages constructed of 1.25 cm galvanized mesh poultry netting. A nylon rope was attached to the cages and then anchored to the river bottom with a cement block. Cages were also anchored to the bottom using pegs or rocks and sometimes attached to a shoreline structure. The mussels were immediately shucked after retrieval, excess water was drained and the soft tissues were weighed, individually wrapped in hexane-rinsed aluminum foil, and placed in plastic bags. Three replicate samples were analysed for contaminants at each station with the exception of six stations where there were six replicates and one station where there were four replicates analysed. Due to inconclusive results for hexachlorobutadiene at all stations, archived mussel tissue at selected stations were analysed to verify the original data. This archived material was analysed for all parameters in addition to hexachlorobutadiene, hence the additional replicates at some stations.

Sampling stations were located at the mouth of tributaries, in the Tonawanda Channel, Chippawa Channel and near known industries, and hazardous waste sites (Figure 1; Appendix A). The cages were usually placed within two to three metres from shore because the study was designed to investigate the impact of shore based sources on water quality rather than ambient river conditions.

Figure 1: Station Locations for Niagara River Mussel Biomonitoring Survey, 1995.



There were five stations on the Canadian side of the river and 18 stations on the U.S. side. There were three new sites on the U.S. side: Black Rock Canal - located upstream of the boat ramps at the Great Lakes Centre field station, Buffalo State College; Tonawanda Channel 600 m upstream of Two Mile Creek and a station in Cayuga Creek located 860 m upstream of the mouth of the creek. One site from a previous survey has been renamed. In 1991 and 1993 mussels were deployed at a station described as an "upstream control for the Occidental Sewer 003". Mussels at this site in 1993 accumulated several chlorinated benzene compounds, mirex and PCBs at concentrations higher than those detected in mussels deployed at the 003 sewer. An explanation provided in the 1993 report (Richman 1994) suggested the possibility of a back eddy near the 003 outfall shifting contaminants upstream. After a review of the 1995 data which was consistent with the 1993 data, it was clear that this site could not be described as an "upstream control" for the 003 sewer. This station was likely impacted by another sewer located 15 m upstream, and mussel contaminant concentrations probably reflected the discharges from this outfall. Influences from two additional sewers located 100 m and 165 m upstream cannot be excluded due to their proximity. The 1997 mussel survey deployed mussels at all the outfalls in front of the Occidental property in an attempt to clarify the source of the contaminants. The station upstream of 003 has been renamed "downstream of Sewer C". Verification of the source of contaminants detected at this station and at the sewer identified as "Sewer C" will continue in the 1997 survey.

At two stations (102nd Street Landfill and Occidental's Sewer 003) a sufficient number of mussels were deployed in cages for long term exposure experiments. Mussels were retrieved after 1 day, 2 days, 3 days and 8,16, 21, 31, 64, 97 and 126 days of exposure. Contaminant data were available for the entire sampling period for the 102nd Street site; however, data were only available for up to 31 days of exposure from the Occidental site. Unfortunately all remaining mussels were removed from the site, possibly during repairs to the outfall.

Analytical Methods

All mussel samples were submitted for chemical analysis at the OMOE laboratory in Etobicoke, Ontario where they were analysed for the following parameters: organochlorine pesticides, total PCB's and chlorinated benzenes (Table 1). Caged mussels were collected from five of the stations for analysis of polychlorinated dibenzo-p-dioxins and polychlorinated Dibenzofurans and from nine stations for analysis of PAHs. All results were reported on a wet weight basis.

All laboratory analytical procedures for contaminants in mussels followed the methodology outlined in the Handbook of Analytical Methods for Environmental Samples (OMOE 1983). Procedural updates for biomaterial analysis were provided in OMOE 1997a to 1997c.

TABLE 1: Mussel tissue was submitted for the following analyses.

All samples were sumbitted for the following analyses		Samples from five stations were were submitted for:	Samples from nine stations were were submitted for:
PCBs (total)	1,3,5-trichlorobenzene	Polychlorinated dibenzo-p-dioxins	Naphthalene
Heptachlor	1,2,4-trichlorobenzene	Polychlorinated dibenzofurans	Acenaphthylene
Aldrin	1,2,3-trichlorobenzene		Acenaphthene
Photomirex	1,2,4,5-tetrachlorobenzene		Fluorene
Mirex	1,2,3,4-tetrachlorobenzene		Phenanthrene
α–BHC	1,2,3,5-tetrachlorobenzene		Anthracene
β–BHC	Pentachlorobenzene		Fluoranthene
γ–BHC	Hexachlorobenzene		Pyrene
α–chlordane	2,4,5-trichlorotoluene		Benzo(a)anthracene
γ–chlordane	2,3,6-trichlorotoluene		Chrysene
pp-DDE	2,6-dichlorobenzyl chloride		Benzo(b)fluoranthene
op-DDT			Benzo(k)fluoranthene
pp-DDD			Benzo(a)pyrene
pp-DDT			Benzo(g,h,i)perylene
Octachlorostyrene			Dibenzo(a,h)anthracene
Toxaphene			Indeno(1,2,3-c,d)pyrene
Hexachloroethane			
Hexachlorobutadiene			

Data Analysis

The range in contaminant concentrations in mussels was provided for replicate samples for each parameter at each station in tables summarized within the report. Means and standard deviations were provided if all replicates had concentrations above the analytical detection limit. Concentrations described as "trace" should be interpreted with caution. These values indicate "a measurable trace amount". All the "raw data" is presented in Appendix B & C. Values at "trace" concentrations are noted by a "t" in the appendix.

RESULTS AND DISCUSSION

Balsam Lake Control Mussels

Analysis of the Balsam Lake mussels (control mussels) for PAHs, organochlorine pesticides, total PCBs, mirex and chlorinated benzenes showed that all compounds analysed were below the method detection limits with the exception of trace concentrations of 1,2,3-Trichlorobenzenes (4 ng/g). This suggests that the detection of contaminants in mussels retrieved from sites along the Niagara River resulted from the exposure of the caged mussels to these compounds during the period of deployment. These compounds were released or deposited into the river from point and non-point sources.

Organochlorine Pesticides and PCBs

Analytical results (Table 2) from the caged mussel study were similar to previous years of monitoring. Trace concentrations of both p,p'-DDE and p,p'-DDD (metabolites of the pesticide DDT) were detected in mussels placed on the Canadian side of the river at the mouth of Frenchman's Creek, and p,p-DDE was detected in mussels at the mouth of Miller's Creek and at Niagara-on-the-Lake. pp′-DDD is rarely detected at most stations but has been consistently found in mussels deployed at Frenchman's Creek. Previous OMOE surveys (Anderson *et al.* 1991, Richman 1992, Richman 1994), detected the highest concentrations of p,p'-DDE in mussels deployed at Fort Erie, however, concentrations in mussels at this station were below the detection limit in 1995. According to the Niagara River upstream/downstream monitoring data, loadings of p,p′-DDE and p,p′-DDT were significantly higher at Fort Erie than Niagara-on-the-Lake in the suspended solids phase from April 1994 to March 1995 (Niagara River Data Interpretation Group, River Monitoring Committee 1997). This trend has been consistently observed for many years of monitoring, suggesting that Lake Erie is a source of DDE and DDT to the Niagara River.

TABLE 2: Range in concentrations (ng/g wet weight) of organochlorine pesticides and PCBs in mussels introduced to the Niagara River for three weeks, 1995. If all replicate samples were above the detection limit the mean and standard deviation was also provided.

Sampling Station	N	α–BHC	β–BHC	γ–BHC	α-Chlordane	γ–Chlordane	Total PCBs	mean	pp'-DDD	pp'-DDE	mean
Detection Limit		1	1	1	2	2	20	(SD)	5	1	(SD)
Canadian Sites											
Fort Erie at Robertson St.	3	.	.	.	.	.	.		.	.	
Frenchmans Creek (mouth)	3	.	.	.	.	.	.		(.)-10	5-19	10
											(7.8)
Millers Creek (mouth)	3	.	.	.	.	.	.		.	(.)-9	
Chippawa Channel	3	.	.	.	.	.	.		.	.	
NOTL	3	.	.	.	.	.	.		.	(.)-4	
US Sites											
Buffalo River	3	(.)-18	(.)-10	.	(.)-4	(.)-4	.		.	.	
Black Rock Canal	3	.	.	.	.	.	.		.	(.)-4	
Tonawanda Channel (upstream of Two Mile Creek)	3	(.)-11	(.)-4	(.)-3	.	.	(.)-240		.	(.)-5	
Two Mile Creek (mouth)	3	.	.	.	.	.	.		.	(.)-5	
Pettit Flume (site B)	3	.	.	.	.	.	.		.	(.)-6	
Gratwick/Riverside Park	6	.	.	.	.	.	.		.	(.)-14	
Wheatfield	3	.	.	.	.	.	.		.	3-4	3
											(0.6)
102nd Street (upstream)	3	.	.	.	.	.	.		.	3-5	4
											(1.0)
102nd Street	6	(.)-9	(.)-3	(.)-2	.	.	(.)-200		.	(.)-4	
Cayuga Creek	3	(.)-26	(.)-17	(.)-3	(.)-6	(.)-8	(.)-120		(.)-10	.	
Sewer C (upstream of sewer 003)	4	(.)-2	(.)-11	.	.	.	(.)-260		.	4-17	10
											(6.7)
Occidental Sewer 003	3	.	.	.	.	.	.		.	.	.
Storm Sewer	3	.	.	.	.	.	.		.	.	
Occidental Sewer 002	3	.	.	.	.	.	(.)-60		.	(.)-6	
Gill Creek (upstream)	3	.	.	.	.	.	120-360	200	.	.	
								(138.5)			
Bloody Run Creek (mouth)	3	.	.	.	.	.	.		.	.	
Balsam Lake Control Mussels	3	.	.	.	.	.	.		.	.	

"." Compound was below the detection limit

Aldrin, Heptachlor, Toxaphene, Mirex, Photomirex, o'p-DDT and p'p-DDT were not detected in any samples analysed.

NOTL=Niagara -on-the-Lake

Consistent with previous surveys since 1980, PCBs and other organochlorine pesticides were not detected in any mussels introduced on the Canadian side of the river.

Hexachlorocyclohexane (α-BHC and β-BHC) was detected in mussels at five sites on the U.S. side of the river; the mouth of the Buffalo River, the Tonawanda Channel 600 metres upstream of Two Mile Creek, the 102nd Street Landfill, downstream of Sewer C associated with the Occidental Chemical Corporation, and at the station in Cayuga Creek. Trace concentrations of γ-BHC were detected in mussels at three of the five stations listed above and α and γ-chlordane were detected in mussels deployed at the mouth of the Buffalo River and at the site in Cayuga Creek at trace concentrations (Table 2). p,p'-DDE was detected at low or trace concentrations at several stations and p,p'-DDD was only detected in Cayuga Creek.

Hexachlorocyclohexane (α-BHC, β-BHC and γ-BHC) has been routinely detected in mussels previously deployed at the 102nd Street Landfill (Kauss and Angelow 1988; Anderson *et al* 1991; Richman 1992; Richman 1993; Richman 1994). It has been estimated that more than 1,500 tons (1,524 tonnes) of BHC were disposed in the 102nd Street Landfill (USEPA/NYSDEC 1993). This waste site is presently being remediated through various containment options and removal of contaminated sediment from the river adjacent to the landfill. With the exception of mussels previously placed at the mouth of Gill Creek and the 102nd Street Landfill, detection of BHC at other sampling sites in past surveys was sporadic. Recent Niagara River upstream/downstream monitoring from April 1994 to March 1995 showed that loadings of α-BHC were significantly higher at Niagara-on-the-Lake in water and suspended sediment when compared with loadings at Fort Erie, suggesting sources of α-BHC in the Niagara River (Niagara River Data Interpretation Group, River Monitoring Committee 1997). Loadings of γ-BHC were also higher at Niagara-on-the-Lake in the water phase. BHC was identified as a Priority Toxic Chemical of Concern for surveillance in the Niagara River by the Niagara River Toxic Committee (NRTC) (NRTC 1984).

PCBs were present in mussels deployed downstream of the 102nd Street Landfill site, adjacent to sewers associated with Occidental Chemical Corporation, in Cayuga Creek and in mussels placed in Gill Creek north of highway 384 (Table 2). PCBs have been consistently detected in some mussels at the 102nd Street Landfill site since 1983, although concentrations varied and variability within a survey was usually high. PCBs have also been detected in mussels deployed at various outfalls in front of the Occidental Chemical Corporation since 1983 suggesting PCBs are bioavailable in this area, however, PCBs have not been detected in mussels placed specifically at the 003 sewer since 1991. Sewer 003 discharges non contact cooling water, treated effluent and surface water runoff (Conestoga Rovers & Associates 1992).

The upper Gill Creek site was upstream of the area remediated for PCBs. High concentrations of PCBs in mussels at this site (range 120-360 ng/g) suggest that source(s) of PCBs still exist in this area. These results were consistent with data from 1993 (the first year of monitoring at this site). NYSDEC has signed an Order of Consent with the Olin Corporation for the remediation of upper Gill Creek sources and sediments (P. Buechi 1997 personal communication). Remediation is expected to begin in 1998. Mussels were deployed at the mouth of Gill Creek on two occasions in 1995, however; in both cases they were removed or drifted downstream. Previous monitoring at the mouth of the creek showed extremely high concentrations of PCBs in deployed mussels consistent with the creek being a significant source of PCBs to the Niagara River (NYSDEC 1991; USEPA/NYSDEC 1993). Concentrations in mussels after contaminated sediment was dredged from the area were lower than concentrations found in previous years.

Since 1987 high concentrations of PCBs have been detected in mussels deployed at the mouth of Two Mile Creek suggesting that this creek was a source of PCBs to the Niagara River. Accordingly, the inability to detect PCBs in mussels in the 1995 survey was inconsistent with previous results. Mussels are known to react to adverse environmental conditions by shell closure (Englund and Heino 1996), however, the mussels at the site did accumulate high concentrations of PAHs (also consistent with past surveys), suggesting that they were actively filtering the water. This site was included in the 1997 survey to verify these results, and was included in a long term deployment study (up to four months) to relate exposure time to PCB tissue concentrations.

Chlorinated Benzenes and Chlorinated Industrial Compounds

Consistent with previous years of mussel monitoring chlorinated benzenes were not detected in any mussels deployed on the Canadian side of the river with the exception of one mussel at the mouth of Miller's Creek which had trace concentrations of hexachlorobenzene (7 ng/g) (Table 3).

Chlorinated benzenes were present in mussels deployed at most stations sampled on the U.S. side of the river. The most frequently detected compounds were; hexachlorobenzene which was detected at all but one station, pentachlorobenzene which was present at all but two stations and 1,2,3,4-tetrachlorobenzene which was detected at ten out of 16 stations. The highest concentrations of pentachlorobenzene and 1,2,3,4-tetrachlorobenzenes were present in mussels at the 102nd Street Landfill and the area associated with the Occidental outfalls (Table 3). High concentrations of hexachlorobenzene were also present in mussels deployed downstream of Sewer C (range 90 to 250 ng/g) and in one mussel located downstream of Gratwick/Riverside Park (range 250 ng/g). Mussels in previous surveys accumulated

TABLE 3: Range in concentrations (ng/g wet weight) of chlorinated benzenes and chlorinated industrial compounds in mussels introduced to the Niagara River for three weeks, 1995. If all replicate samples were above the detection limit the mean and standard deviation was also provided.

Sampling Station	N	Hexa-chlorobutadiene	Hexa-chlorobenzene	mean	Hexa-chloroethane	mean	Octa-chlorostyrene	mean	Penta-chlorobenzene	mean	2,3,6-Trichlorotoluene	mean	2,4,5-Trichlorotoluene	mean
Detection Limit		1	1	(SD)	1	(SD)	1	(SD)	1	(SD)	1	(SD)	1	(SD)
Canadian Sites														
Fort Erie at Robertson St.	3	ND	.		.		.		.		.		.	
Frenchmans Creek (mouth)	6	.	.		.		.		.		.		.	
Millers Creek (mouth)	6	.	(.)-7		.		.		.		.		.	
Chippawa Channel	3	ND	.		.		.		.		.		.	
NOTL	3	ND	.		.		.		.		.		.	
US Sites														
Buffalo River (mouth)	6	.	(.)-5		.		.		(.)-21		.		.	
Black Rock Canal	6	.	.		(.)-41		.		2-3	3	.		(.)-18	
										0.6				
Tonawanda Channel (upstream of Two Mile Creek)	3	ND	(.)-62		.		.		(.)-380		.		.	
Two Mile Creek (mouth)	3	ND	(.)-5		.		.		2-3	3	.		.	
										(0.6)				
Pettit Flume (site B)	3	ND	5-72	36	.		.		3-76	37	.		.	
				(33.7)						(36.7)				
Gratwick/Riverside Park	6	.	(.)-250		.		(.)-60		2-78	52	.		.	
										43.3				
Wheatfield	3	ND	4-8	6	.		.		3	3	.		.	
				(2)						(0)				
102nd Street (upstream)	3	ND	3-4	3	.		.		2-3	3	.		.	
				(0.6)						(0.6)				
102nd Street	6	.	4-74	28	.		(.)-2		2-400	175	.		(.)-5	
				(26.9)						(154.4)				
Cayuga Creek	3	ND	(.)-5		(.)-15		.		(.)-25		.		(.)-8	
Sewer C (upstream sewer 003)	4	.	90-250	157	.		(.)-42		35-580	186	.		4-7	5
				(76.8)						(263.2)				(1.2)
Occidental's S. 003	3	ND	12-40	25	.		.		32-140	74	12-46	24	6-60	29
				(14.1)						(57.8)		(19.1)		(27.7)
Storm Sewer	3	ND	7-15	12	.		.		12-20	17	(.)-6		(.)-7	
				(4.2)						(4.4)				
Occidental S. 002	3	ND	4-24	13	.		(.)-2		.		.		.	
				(10.3)										
Gill Creek (upstream)	3	ND	2-4	3	2-5	3	2-3	3	.		.		.	
				(1.2)		(1.5)		(1.5)						
Bloody Run Creek	3	ND	44-81	57	.		(.)-2		22-40	31	.		.	
				(20.5)						(9)				
Balsam Lake Control Mussels	3	.	.		.		.		.		.		.	

"." Compound was below the detection limit

ND = No Data

Table 3 continued:

Sampling Station	N	1,2,3-Trichlorobenzene	mean	1,2,3,4-Tetrachlorobenzene	mean	1,2,3,5-Tetrachlorobenzene	1,2,4-Trichlorobenzene	1,2,4,5-Tetrachlorobenzene	1,3,5-Trichlorobenzene
Detection Limit		2	(SD)	1	(SD)	1	2	1	2
Canadian Sites									
Fort Erie at Robertson St.	3	.		.		.	.	.	.
Frenchmans Creek (mouth)	6	.		.		.	.	.	.
Millers Creek (mouth)	6	.		.		.	.	.	.
Chippawa Channel	3	.		.		.	.	.	.
NOTL	3	.		.		.	.	.	.
US Sites									
Buffalo River (mouth)	6	(.)-3		.		.	(.)-3	.	.
Black Rock Canal	6	.		.		.	.	.	.
Tonawanda Channel (upstream of	3	(.)-16		(.)-310		(.)-30	(.)-30	(.)-54	(.)-16
Two Mile Creek)									
Two Mile Creek (mouth)	3	.		(.)-2		.	.	.	.
Pettit Flume (site B)	3	.		3-36	18	(.)-28	.	(.)-20	.
					(16.7)				
Gratwick/Riverside Park	6	.		(.)-34		(.)-19	.	(.)-15	.
Wheatfield	3	.		.		.	.	.	.
102nd Street (upstream)	3	.		.		.	.	.	.
102nd Street	6	(.)-11		(.)-400		(.)-16	(.)-14	(.)-89	(.)-9
Cayuga Creek	3	.		(.)-17		.	.	.	.
Sewer C (upstream sewer 003)	4	.		13-480	132	.	.	.	.
					(232.0)				
Occidental's S. 003	3	.		30-120	63	.	.	.	.
					(49.8)				
Storm Sewer	3	.		13-20	17	.	.	.	.
					(3.5)				
Occidental S. 002	3	.		8-18	14	.	.	.	.
					(5.1)				
Gill Creek (upstream)	3	.		.		.	.	.	.
Bloody Run Creek	3	.		.		.	.	.	.
Balsam Lake Control Mussels	3	4	4	.		.	.	.	.
			(0)						

"." Compound was below the detection limit

ND = No Data

2,6-dichlorobenzyl chloride was nct detected in any samples analysed.

chlorinated benzenes at the Sewer C station, however, detection of these compounds at the Gratwick/Riverside site have not been consistent over time.

Loadings of pentachlorobenzene, hexachlorobenzene and 1,2,3,4-tetrachlorobenzene were all significantly higher ($p < 0.01$) in water and suspended sediment at Niagara-on-the-Lake than at Fort Erie in 1994/95 suggesting sources from the Niagara River (Niagara River Data Interpretation Group, River Monitoring Committee 1997). The mussel data is consistent with the Upstream/Downstream data and identifies source areas throughout the upper river where these compounds were bioavailable.

Although hexachlorobenzene, pentachlorobenzene and tetrachlorobenzenes were detected at most stations on the U.S. side of the river, trichlorobenzenes were limited to a few sites: 102nd Street Landfill, the Tonawanda Channel station and the mouth of the Buffalo River. Concentrations in mussels from the Buffalo River were trace and should be viewed with caution considering the presence of 1,2,3-trichlorobenzenes in the Balsam Lake control mussels (Table 3). The detection of trichlorobenzenes at the Tonawanda Channel station also requires caution since two of the three mussels at this site did not have detectable concentrations of any contaminants although the third replicate accumulated several parameters particularly the chlorinated benzenes. Mussels deployed at the 102nd Street Landfill have consistently had detectable concentrations of trichlorobenzenes since the 1989 survey, suggesting that this area is a source of these compounds.

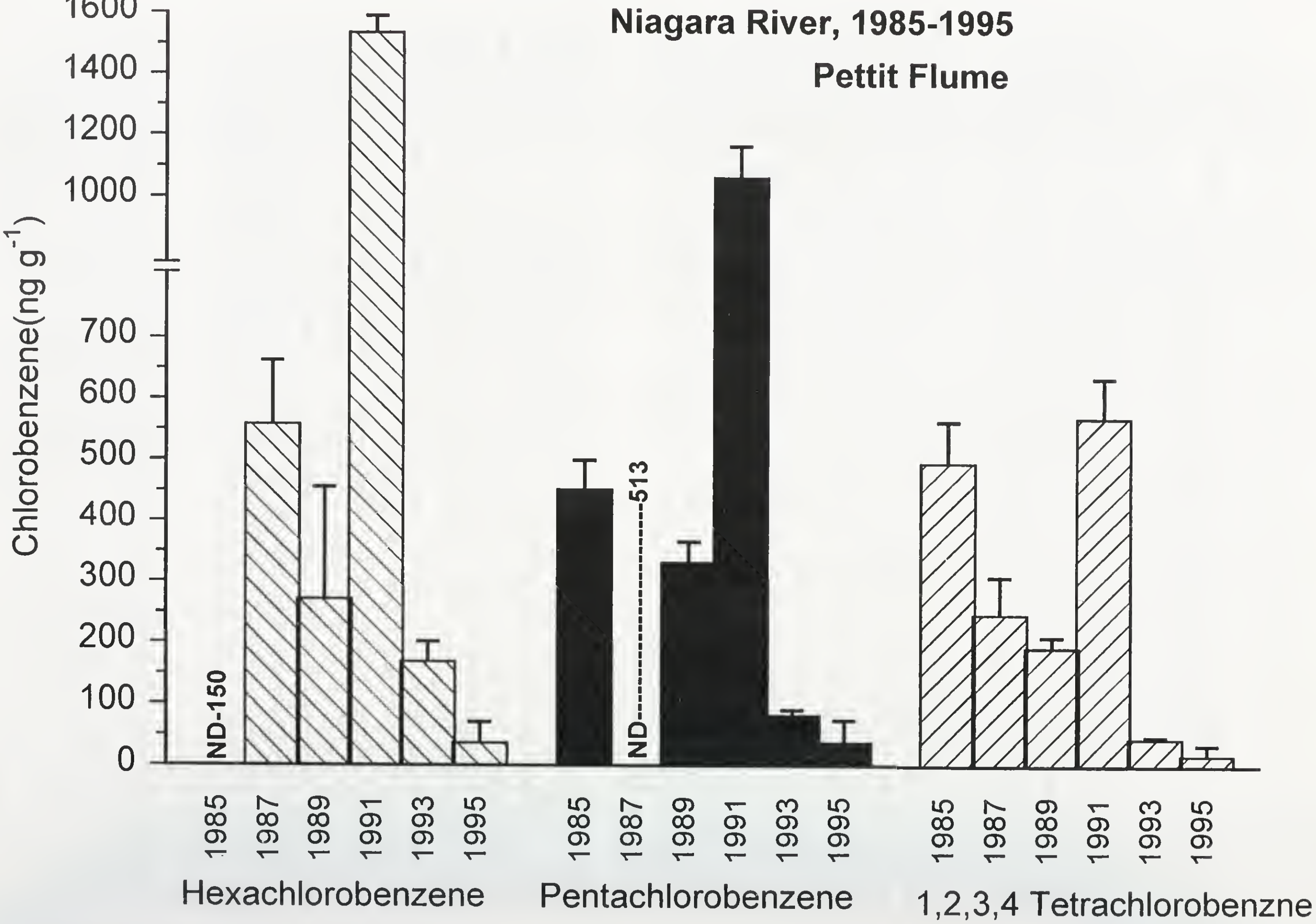
Concentrations of chlorinated benzenes typically found in caged mussels at the Pettit Flume cove and the mouth of the flume in past OMOE surveys were lower in 1995 than concentrations found in previous years, and likely reflect the success of the remedial actions completed in 1993 (Figure 2). The Pettit Flume is a storm sewer which received waste water from the Occidental Chemical Corporation Durez Division and surrounding hazardous waste sites (Geologic Testing Consultants LTD. 1984). The cove was filled with waste products which included chlorinated phenols, chlorotoluene, other organic and inorganic compounds and phenol tar containing chlorinated benzenes (Interagency Task Force on Hazardous Waste 1979; Raven 1991; USEPA/NYSDEC 1993). The decrease in mussel tissue concentrations of chlorinated benzenes in 1995 was attributed to the remediation rather than typical variability in tissue concentrations observed between surveys, because of the method of remediation (dewatering of the cove and removal of contaminated sediment), and the consistently high concentrations of these compound previously detected prior to remediation.

Hexachlorobenzene was the only chlorinated benzene detected in mussels deployed in Gill Creek suggesting that this area was not a significant source of chlorinated benzenes to the Niagara River. This data was consistent with the 1993 data. Concentrations of chlorinated benzenes in general at the mouth of Gill Creek have

Figure 2: Caged Mussel Tissue Concentrations (mean±SD, n=3)

Niagara River, 1985-1995

Pettit Flume



ND= Not Dectected

always been low in past surveys as well (Anderson *et al* 1991; Richman 1992; Richman 1993; Richman 1994). Concentrations of chlorinated benzenes were below the detection limit or at trace levels in mussels at the mouth of Two Mile Creek, downstream of Wheatfield and in Cayuga Creek.

Octachlorostyrene was detected in mussels at only six stations. Tissue concentrations were trace with the exception of one mussel at Gratwick/Riverside Park (60 ng/g) and three of the four replicates at the site downstream of Sewer C located in front of the Occidental Chemical Corporation (14 ng/g, 29 ng/g and 42 ng/g). Octachlorostyrene has not been routinely accumulated by mussels deployed at the various outfalls in front of the Occidental property.

The highest concentrations of 2,3,6-trichlorotoluene (range 12-46 ng/g) and 2,4,5-trichlorotoluene (range 6-60 ng/g) were detected in mussels placed at Occidental Sewer 003 and trace concentrations were present in one mussel at the storm sewer downstream of Sewer 003. Chlorotoluene was a known contaminant in Occidental's effluent (NRTC 1984) and has been consistently accumulated by mussels deployed at the outfalls associated with the Occidental Chemical Corporation property (Figure 3). Trace concentrations of 2,4,5-trichlorotoluene were present in mussels deployed downstream of Sewer C also associated with the Occidental Chemical Corporation, at Cayuga Creek, and in one mussel at the 102nd Street Landfill. Concentrations were also present in two of the three mussels placed in the Black Rock Canal (12 and 18 ng/g). Chlorotoluenes were used in the production of pesticides, herbicides, dyes, pharmaceuticals, peroxides and as solvents since the 1930s (Durham and Oliver 1983).

Initial results for hexachlorobutadiene in mussel tissue were inconclusive and deemed invalid. Archived material from seven stations were used to validate the original data. The results from the archived material showed concentrations below the detection limit for all samples which was consistent with previous mussel monitoring surveys.

Polycyclic Aromatic Hydrocarbons (PAHs)

Consistent with previous OMOE surveys, high concentrations of benzo(a)anthracene, benzo(b)fluoranthene, chrysene, fluoranthene and pyrene were present in mussels deployed at the mouth of Two Mile Creek in two of the three replicates analysed suggesting that this creek is a source of these PAHs to the Niagara River (Table 4). These mussels also had detectable concentrations of pp'-DDE and chlorinated benzenes while the third mussel did not accumulate any compounds and may not have been filtering (Englund and Heino 1996). Concentrations of the same PAH compounds were also high in two of the three mussels deployed in Cayuga Creek (with the exception of benzo(a)anthracene which was high in only one mussel in Cayuga Creek) (Table 4).

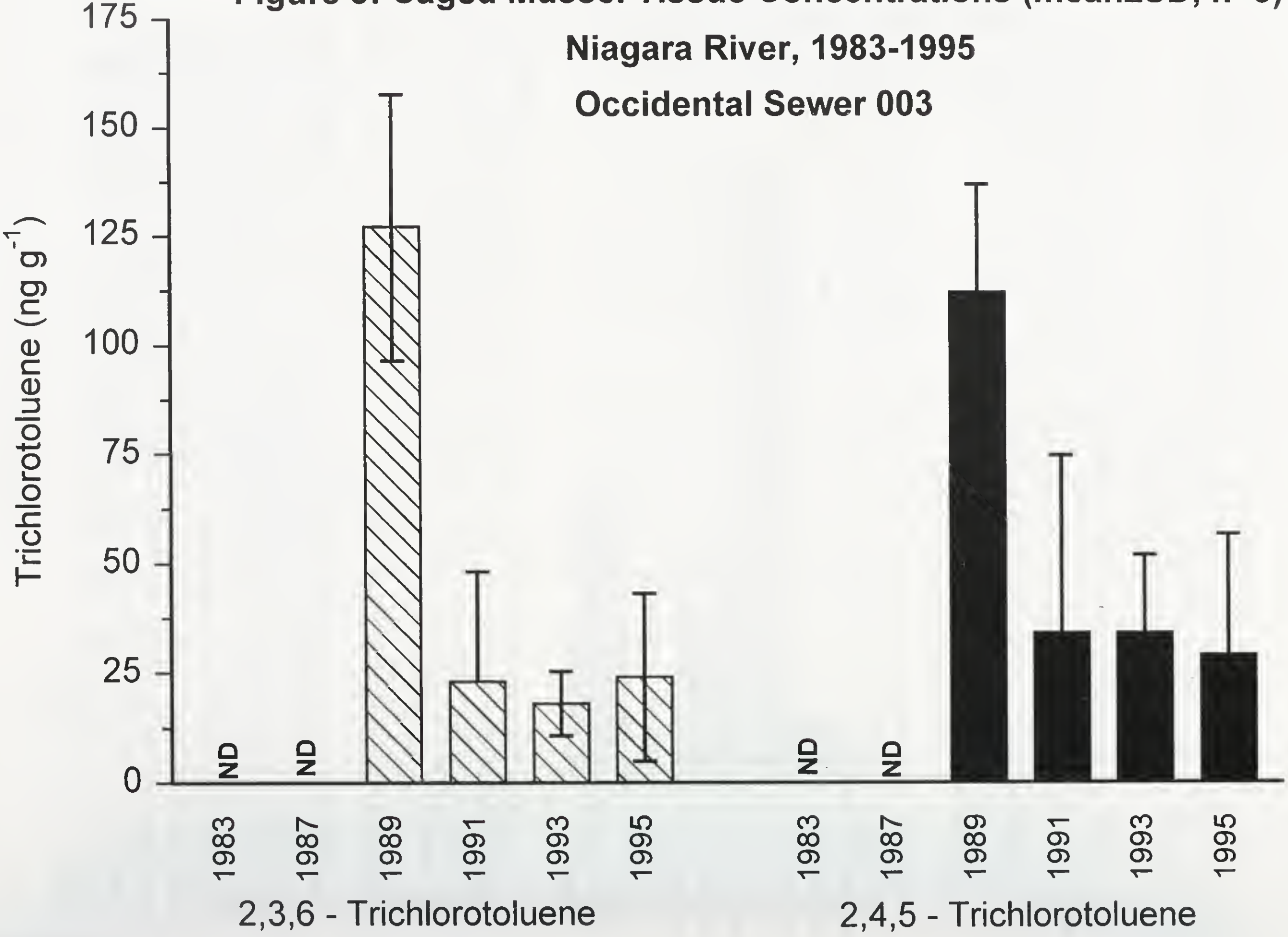


Figure 3: Caged Mussel Tissue Concentrations (mean±SD, n=3)
Niagara River, 1983-1995
Occidental Sewer 003

ND= Not Dectected

TABLE 4: Range in concentrations (ng/g wet weight) of polycyclic aromatic hydrocarbons in mussels introduced to the Niagara River for three weeks, 1995. If all the replicate samples were above the detection limit the mean and standard deviation was also provided.

Parameters	Detection Limit	Fort Erie at Robertson Street	Millers Creek	Buffalo River	Black Rock Canal	mean(SD)
Acenapthene	20	.	(.)-60	.	(.)-240	
Anthracene	20	.	.	.	.	
Benzo(A) Anthracene	20	.	.	(.)-100	(.)-100	
Benzo(A) Pyrene	40	.	.	(.)-80	.	
Benzo(B) Fluoranthene	20	.	.	(.)-440	(.)-100	
Benzo(K) Fluoranthene	20	.	.	(.)-120	(.)-80	
Chrysene	20	.	.	(.)-200	40-80	87 (80.8)
Fluoranthene	20	.	(.)-40	(.)-340	40-260	120 (121.6)
Fluorene	20	(.)-60	(.)-40	(.)-40	(.)-180	
Benzo (G-H-I) Perylene	40	.	.	(.)-160	(.)-80	
Indeno (1-2-3 C-D) Pyrene	40	.	.	(.)-120	.	
Napthalene	20	.	(.)-40	.	(.)-40	
Phenanthrene	20	.	.	.	40-180	87 (80.8)
Pyrene	20	.	.	(.)-300	40-260	113(127)

Parameters	Detection Limit	Two Mile Creek (upstream)	Two Mile Creek	mean(SD)	Cayuga Creek	NOTL
Acenapthene	20	.	(.)-60		(.)-40	(.)-360
Anthracene	20	.	.		.	(.)-40
Benzo(A) Anthracene	20	.	(.)-560		(.)-160	(.)-60
Benzo(A) Pyrene	40	.	.		.	.
Benzo(B) Fluoranthene	20	.	(.)-180		(.)-240	(.)-60
Benzo(K) Fluoranthene	20	.	(.)-60		(.)-60	.
Chrysene	20	.	(.)-420		(.)-220	(.)-60
Fluoranthene	20	.	40-680	453(358.5)	(.)-360	(.)-360
Fluorene	20	.	(.)-80		(.)-40	(.)-220
Benzo (G-H-I) Perylene	40	.	.		.	.
Indeno (1-2-3 C-D) Pyrene	40	.	.		.	.
Napthalene	20	.	(.)-260		.	(.)-340
Phenanthrene	20	.	(.)-180		(.)-60	(.)-460
Pyrene	20	.	(.)-460		(.)-320	(.)-240

Mussels from Niagara-on-the-Lake, the Buffalo River and Black Rock Canal had high concentrations of several PAH compounds (for example acenapthene, benzo(b)fluoranthene, fluoranthene, chrysene, naphthalene, phenanthrene); however, the high values were only present in one mussel at each station.

Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzofurans

Dioxins and furans were analysed in one composite sample (four mussels per site) from each of five sites and from the Balsam Lake control group. Dioxins and furans were not detected in the Balsam Lake control mussel or mussels deployed at Niagara-on-the-Lake and at Fort Erie with the exception of 2.7 pg/g tetrachlorodibenzo-p-dioxin (T4CDD) at Niagara-on-the-Lake (Table 5).

Dioxin concentrations in the mussels analysed from the 102nd Street Landfill were two to three times higher than concentrations in surveys from 1987 to 1993 for hexa, hepta and octachlorinated dibenzo-p-dioxins (Figure 4 & 5). Concentrations of furan congeners, with the exception of tetrachlorinated dibenzofurans (T4CDF), were also higher in 1995 than in 1991 and 1993, however, the highest concentrations of tetra, penta and hexachlorinated dibenzofurans were detected in mussels deployed in 1987. There were high concentrations of 2,3,7,8-T4CDD (89 pg/g) in mussel tissue and 2,3,7,8-T4CDF (31 pg/g). With the exception of 1,2,3,7,8,9-TCDF all the dioxin/furan toxic isomers analysed were present in mussels deployed at this site.

Most of the dioxin and furan congeners were present in the mussel analysed from Cayuga Creek, however, concentrations were low relative to those at the 102nd Street Landfill site. 2,3,7,8-T4CDD was present at 16 pg/g and 2,3,7,8-T4CDF was 6 pg/g. 2,3,7,8-T4CDD represented 94% of the total T4CDD.

Bloody Run Creek and the nearby seepages which run down the face of the Niagara Gorge were historically contaminated from the Hyde Park landfill. Prior to site remediation, the drainage from the Hyde Park landfill was a major source of dioxin contamination to the Niagara River (Gradient Corporation 1990). Remediation of the landfill and Bloody Run Creek was completed in 1994. In 1993 high concentrations of dioxins and furans were detected in deployed mussels and sediment. In the 1994 and 1995 survey, however, dioxin and furan concentrations were considerably lower in mussel tissue (Figure 6&7). In 1995, isomer patterns in mussel tissue were consistent with previous surveys with 100% of the T4CDD detected as 2,3,7,8-T4CDD at high concentrations (120 pg/g). Concentrations of 2,3,7,8-T4CDF were low (6 pg/g) and only 12% of the total congener group. The presence of other toxic isomers in mussel tissue were low relative to mussels placed at the 102nd Street

TABLE 5: Concentrations of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans in mussels introduced to the Niagara River for three weeks, 1995. Concentrations are in pg/g (wet weight). n=1

Parameters	NOTL (Ont.)	Fort Erie Robertson Street (Ont.)	Cayuga Creek (NY)	Bloody Run Creek (NY)	102nd Street (NY)
T4CDD (total)	$2.7^{(1)}$	.	$17^{(2)}$	$120^{(1)}$	$110^{(6)}$
P5CDD (total)	.	.	$7.9^{(2)}$	$13^{(2)}$	$58^{(5)}$
H6CDD (total)	.	.	$12^{(5)}$	$44^{(5)}$	$270^{(6)}$
H7CDD (total)	.	.	$14^{(2)}$	$25^{(2)}$	$520^{(2)}$
O8CDD (total)	.	.	26	9.3	680
T4CDF (total)	.	.	$19^{(5)}$	$50^{(5)}$	$120^{(13)}$
P5CDF (total)	.	.	$9.8^{(2)}$	$39^{(7)}$	$280^{(10)}$
H6CDF (total)	.	.	$6.2^{(2)}$	.	$300^{(8)}$
H7CDF (total)	.	.	.	.	$110^{(3)}$
O8CDF (total)	.	.	.	.	96
2378TCDD	.	.	16	120	89
2378TCDF	.	.	6	6.2	31
12378PCDD	.	.	.	.	8.3
12378PCDF	.	.	.	.	15
23478PCDF	.	.	1.8	3.2	23
123478HCDD	.	.	.	.	4
123678HCDD	.	.	2.4	12	60
123789HCDD	.	.	1.5	5.6	25
234678HCDF	.	.	.	.	5
123478HCDF	.	.	2.9	6	140
123678HCDF	.	.	.	.	26
123789HCDF	.	.	.	.	.
1234678HCDD	.	.	8.2	17	310
1234678HCDF	.	.	.	.	66
1234789HCDF	.	.	.	.	19

$^{()}$ Number of isomers detected in the congener group

"." Compound was below the detection limit

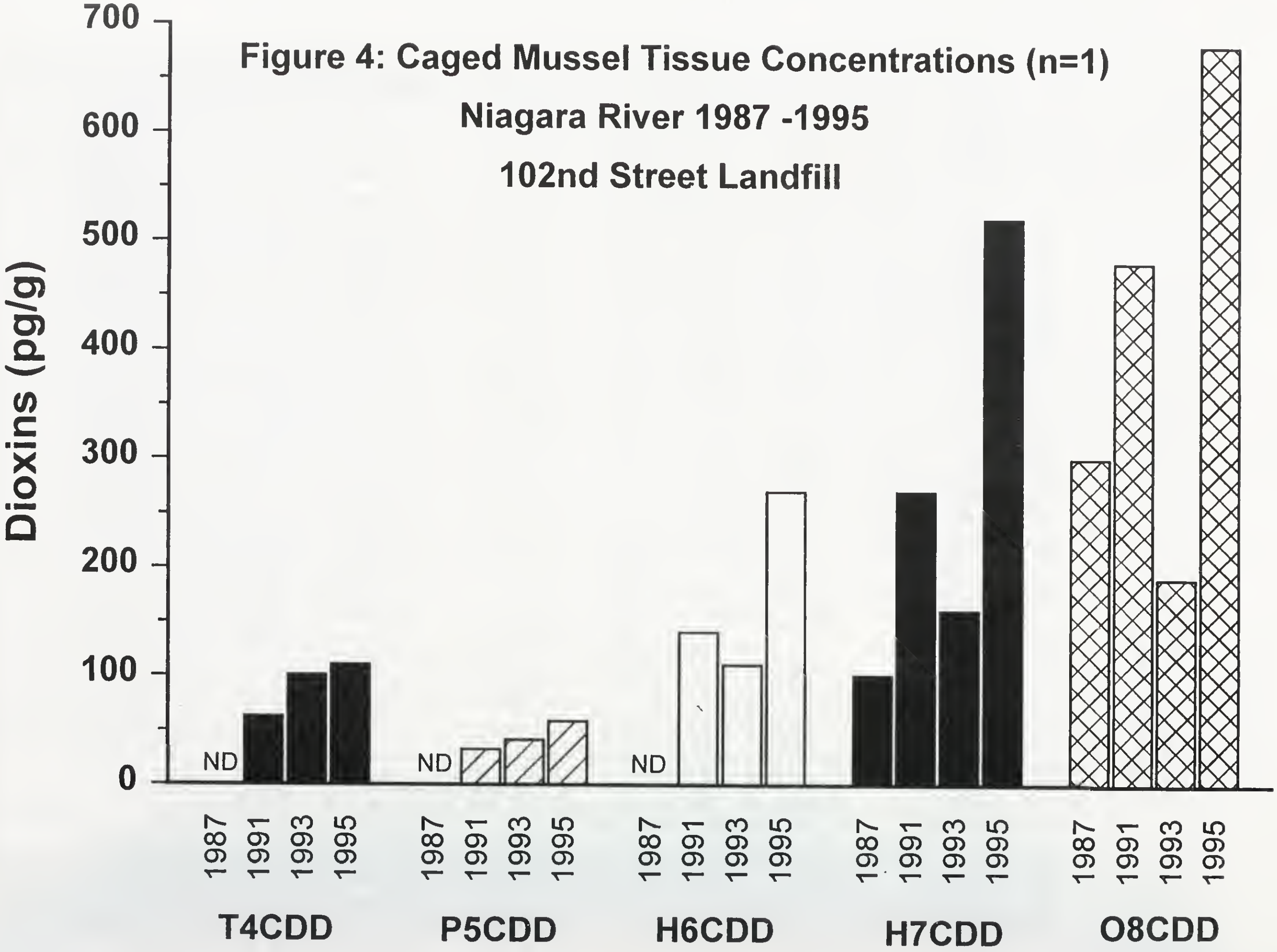
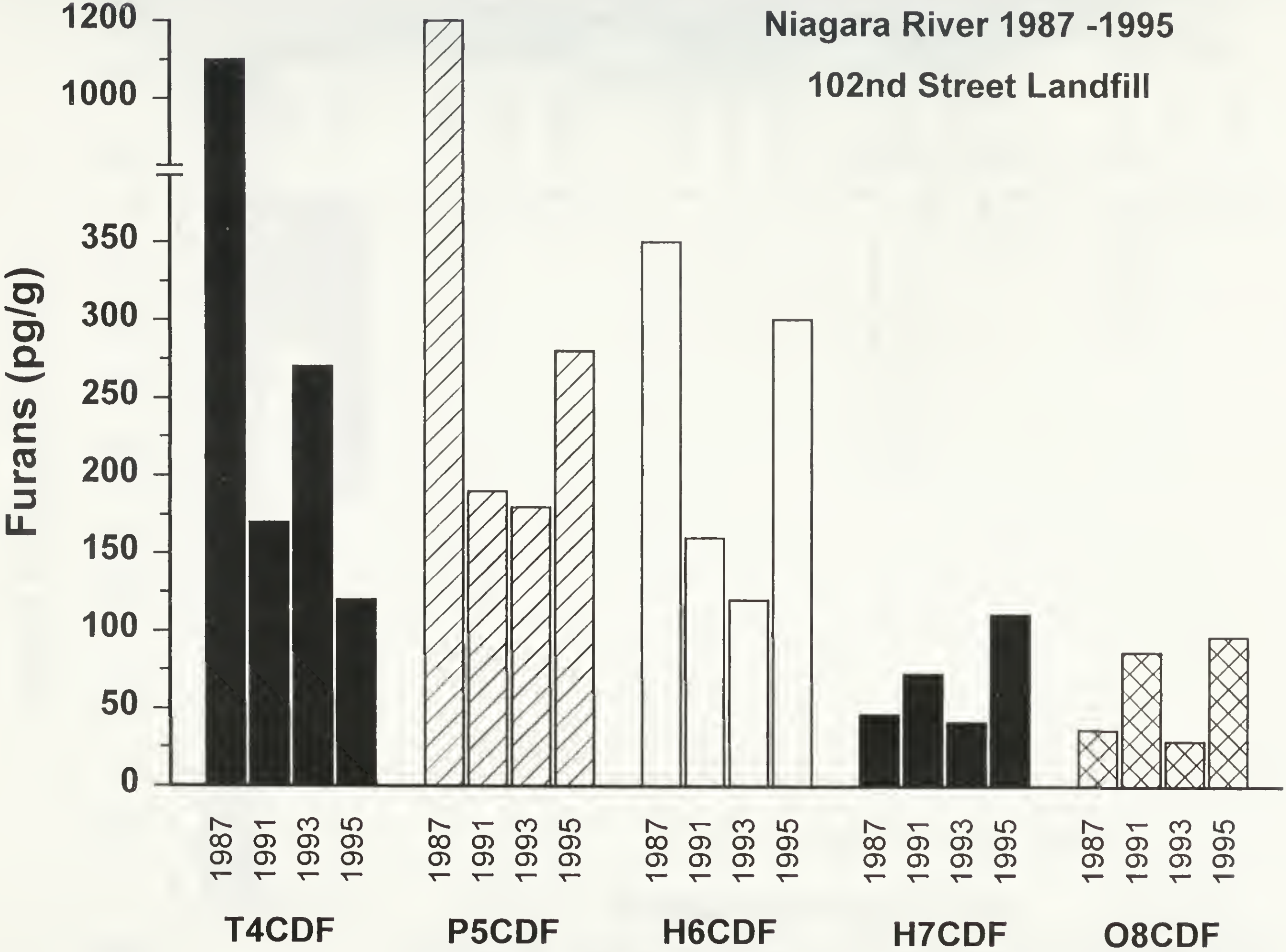


Figure 4: Caged Mussel Tissue Concentrations (n=1)
Niagara River 1987 -1995
102nd Street Landfill

Figure 5: Caged Mussel Tissue Concentrations (n=1)

Niagara River 1987 -1995

102nd Street Landfill



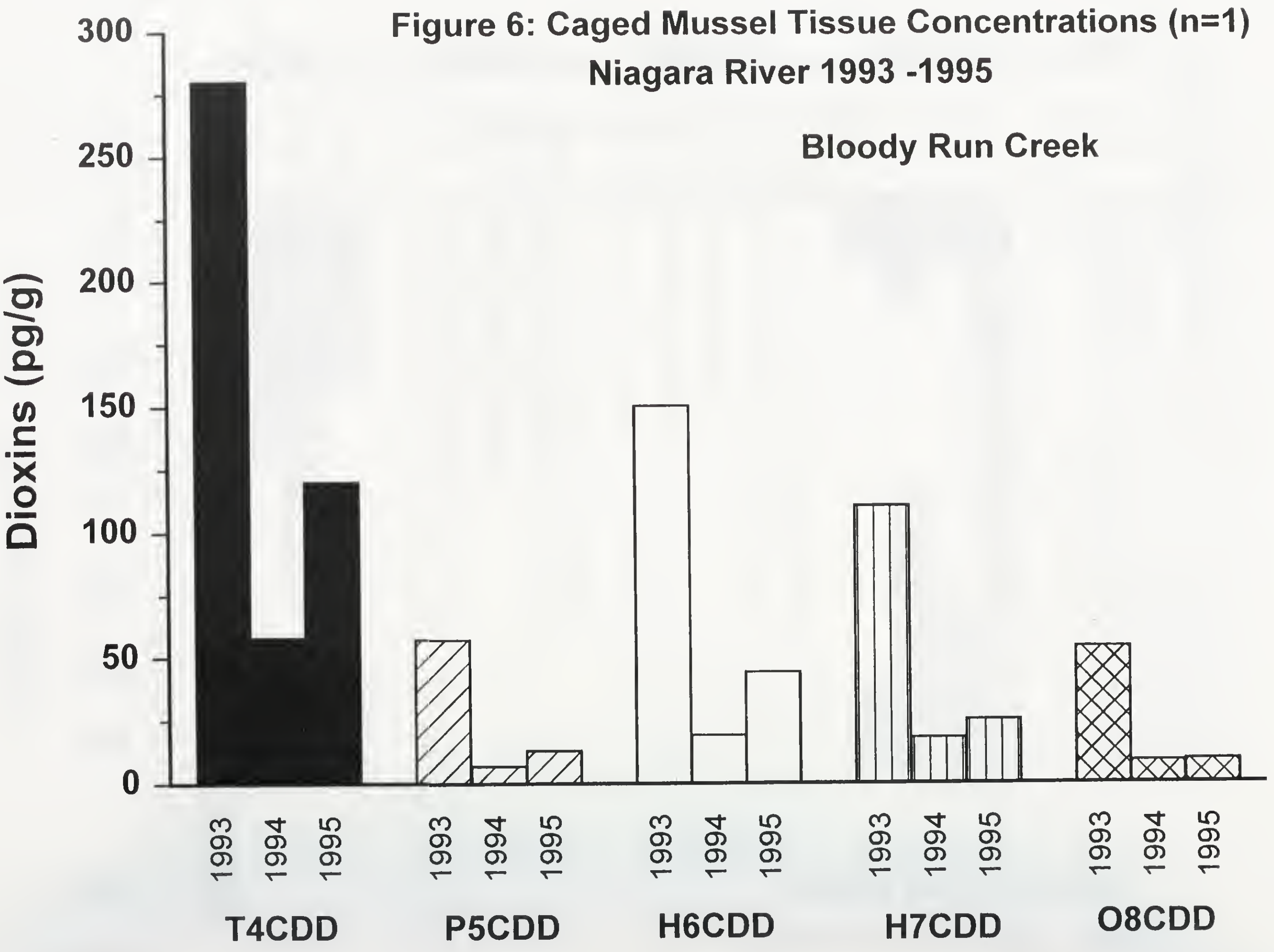


Figure 6: Caged Mussel Tissue Concentrations (n=1)
Niagara River 1993 -1995

Bloody Run Creek

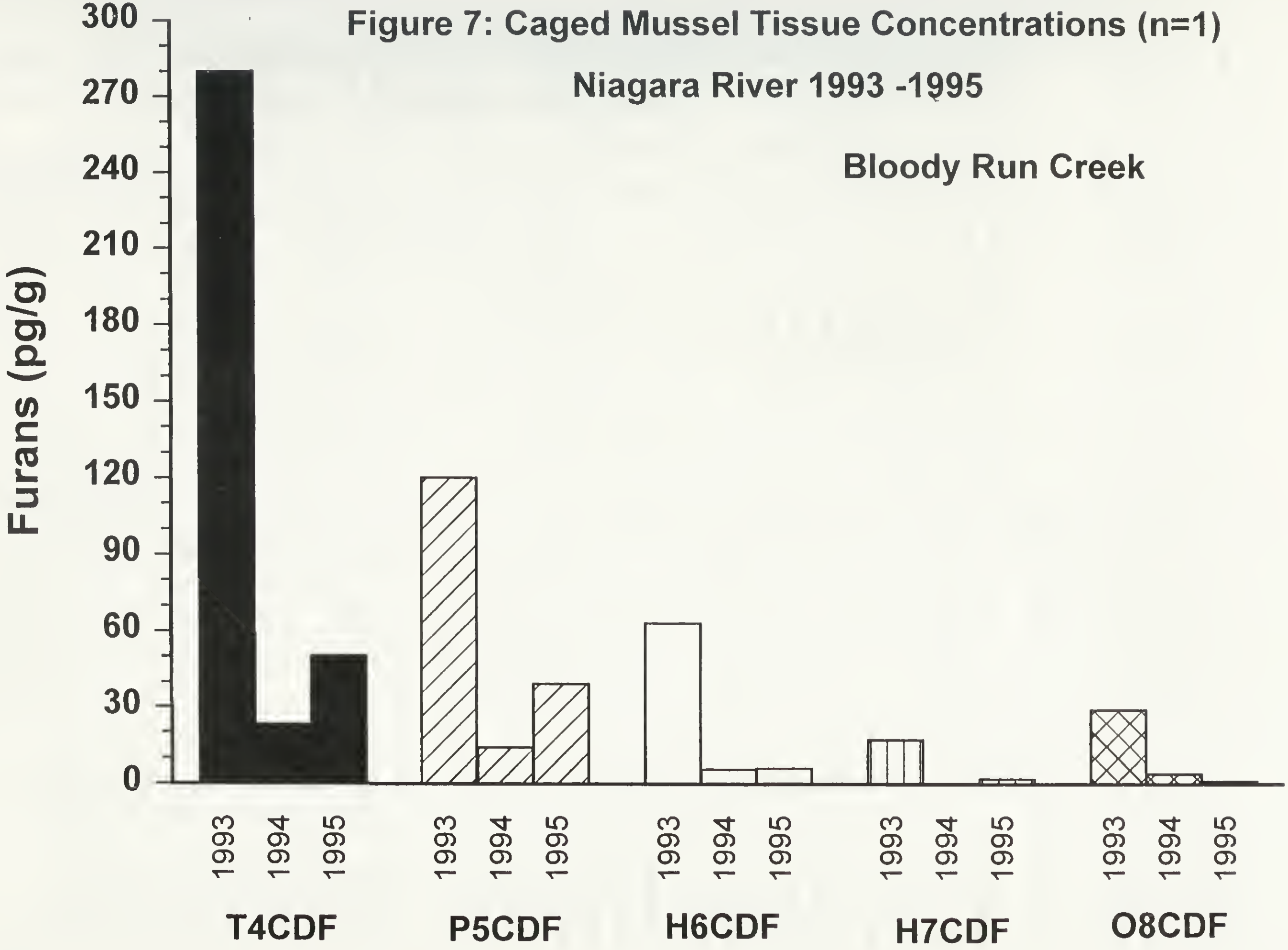


Figure 7: Caged Mussel Tissue Concentrations (n=1)

Niagara River 1993 -1995

Bloody Run Creek

Landfill site and there were distinct isomer patterns for the two monitoring sites. Although concentrations in mussels were lower than previously measured, this site will be monitored in future surveys since the contaminated sediment covered along the Niagara River shoreline and at the mouth of the creek may continue to be a source. Water levels fluctuate daily to maintain the operation of the hydro generating stations thereby routinely submerging and then exposing the contaminated shoreline.

Long Term Deployment of Caged Mussels

Contaminant uptake patterns, tissue concentrations and the parameters accumulated in mussels deployed at two sites for varied time periods were different suggesting that the mussels were monitoring site specific near shore water quality (Table 6 & 7). Mussels deployed at the 102nd Street Landfill accumulated chlorinated benzenes after 24 hours of exposure compared with control mussels from Balsam Lake which did not accumulate any of the parameters that were analysed. Concentrations of all chlorinated benzenes analysed in mussels at 102nd Street gradually increased and peaked after three days of exposure and then gradually decreased at eight and sixteen days. Contaminant concentrations remained constant until day 64. There was an increase in tissue concentrations at day 97 and 126 days (Figure 8 to 12). This pattern was consistent for all the chlorinated benzenes and α-BHC. Tissue concentrations of γ-BHC and β-BHC were low throughout the deployment period but concentrations also increased at day 97 following the same pattern previously described. This distinct pattern of contaminant uptake and depuration in mussels deployed at this site for all parameters strongly suggests that these compounds were all coming from the same source. The contaminants accumulated by the mussels were consistent with the known contaminants stored in the 102nd Street Landfill (Interagency Task Force on Hazardous Wastes 1979). Chlorinated benzenes with the highest tissue concentrations were 1,2,3,4-tetrachlorobenzene and pentachlorobenzene, typical of previous years of short term exposure monitoring.

PCB uptake patterns were different than chlorinated benzenes. Tissue concentrations of PCBs were below the detection limit (20 ng/g) for the first two days, increased to 40 ng/g after three days of exposure and then remained stable until day 31 when PCBs increased to a mean of 67 ng/g and stayed at that concentration for the entire study (Figure 13). This pattern of bioaccumulation was more representative of a continuous low level source than short term contaminant pulses entering the aquatic environment. The different uptake patterns suggest either a different contaminant source or they may be characteristic of the specific compounds. The octanol-water partition coefficients (log K_{ow}) for chlorinated benzenes are lower than for PCBs and although this group of compounds is highly bioaccumulative it may respond faster to changing environmental conditions (Oliver 1987; Hawker and Connell 1985). Fluctuations in tissue concentrations of hexachlorobenzene and pentachlorobenzene were also observed in long term deployment studies with caged mussels in the

TABLE 6: Mean concentrations (ng/g wet weight) +/- standard deviation (SD) of chlorinated benzenes and chlorinated industrial compounds in mussels introduced to the Niagara River for varied deployment times, 1995.

	Hexa-chlorobenzne		Penta-chlorobenzene		2,3,6-Trichlorotoluene		2,4,5-Trichlorotoluene		1,2,3-Trichlorobenzene	
102nd Street Landfill Deployment	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
1 day	18	1.5	203	15.3	.		.		13	1.2
2 days	30	4.0	280	34.6	.		.		21	6.1
3 days	37	8.4	410	65.6	.		.		31	5.0
8 days	36	5.7	343	5.8	.		.		17	4.2
16 days	23	6.0	227	90.7	.		.		13	3.1
21 days	28	26.9	175	154.4	.		2	1.6	6	4.6
31days	18	2.3	143	15.3	.		.		16	6.9
64 days	26	11.0	207	83.9	.		.		15	4.2
97 days	47	10.4	510	87.2	.		.		31	6.1
126 days	47	6.5	557	32.1	.		.		49	16.3
Occidental Sewer 003 Deployment	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
1 day	.		2	1.5	4	1.5	6	3.2	4	0.0
2 days	.		4	0.6	4	0.6	5	0.6	4	0.0
3 days	2	0.0	8	1.5	5	1.2	10	2.0	5	1.2
8 days	3	0.6	13	2.0	4	1.2	6	2.1	4	0.0
16 days	12	4.2	52	32.9	34	23.6	47	36.5	6	2.0
21 days	25	14.1	74	57.9	24	19.1	29	27.7	2	0.0
31 days	8	2.3	20	7.8	7	3.0	8	4.0	4	0.0

n=3 for all sampling events with the exception of the 21 day retrieval from 102nd Street landfill where n=6

"." Compound was below the detection limit

Table 6 continued:

	1,2,3,4-Tetrachlorobenzene		1,2,3,5-Tetrachlorobenzene		1,2,4-Trichlorobenzene		1,2,4,5-Tetrachlorobenzene		1,3,5-Trichlorobenzene	
102nd Street Landfill Deployment	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
1 day	307	35.1	35	3.5	5	5.8	27	2.3	15	2.3
2 days	357	76.4	37	7.8	17	6.1	32	8.6	18	5.3
3 days	710	88.9	64	8.7	25	6.1	48	5.3	18	2.0
8 days	397	55.1	25	20.8	12	4.0	23	19.6	7	2.3
16 days	233	102.1	27	11.5	11	4.2	20	9.9	11	4.6
21 days	177	155.4	7	7.1	7	5.8	31	36.4	5	3.3
31days	180	30.0	14	3.8	16	10.6	18	3.1	6	3.5
64 days	220	72.1	20	9.5	13	6.4	22	4.5	5	2.3
97 days	693	124.2	55	19.9	25	5.0	50	4.0	5	1.2
126 days	890	60.8	66	12.9	44	22.7	76	21.0	11	6.1
Occidental Sewer 003 Deployment	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
1 day	9	1.5	.		.		.		.	
2 days	11	2.1	.		.		.		.	
3 days	18	3.5	.		.		.		.	
8 days	19	3.1	.		.		.		.	
16 days	85	63.3	5	4.0	7	4.2	4	3.6	.	
21 days	63	49.8	.		.		.		.	
31 days	16	5.6	.		.		.		.	

n=3 for all sampling events with the exception of the 21 day retrieval from 102nd Street landfill where n=6

"." Compound was below the detection limit

TABLE 7: Mean concentrations (ng/g wet weight) +/- standard deviation (SD) of organochlorine pesticides and PCBs in mussels introduced to the Niagara River for varied deployment times, 1995.

	α–BHC		β–BHC		γ–BHC		Total PCBs		pp'-DDE	
102nd Street Landfill Deployment	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
1 day	14	1.5	4	0.6	2	1.2	.		2	1.2
2 days	17	3.1	3	1.5	4	0.0	.		.	
3 days	22	3.0	4	2.6	5	0.6	40	0.0	3	2.9
8 days	10	1.5	5	3.2	3	0.6	40	0.0	.	
16 days	7	2.6	2	2.3	1	0.6	40	0.0	.	
21 days	4	3.8	2	0.8	1	0.4	50	73.5	2	1.2
31 days	10	0.6	2	1.2	3	0.0	67	11.5	.	
64 days	8	2.6	4	1.0	2	1.2	67	23.1	.	
97 days	15	4.7	6	1.5	5	1.2	60	20.0	.	
126 days	76	21.5	26	3.6	22	6.7	67	23.1	.	
Occidental Sewer 003 Deployment	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
1 day	4	2.6	2	1.2	.		.		.	
2 days	.		.		.		.		.	
3 days	.		.		.		.		.	
8 days	.		.		.		.		.	
16 days	4	2.3	3	2.1	.		.		.	
21 days	.		.		.		.		.	
31 days	2	1.2	2	1.7	.		.		.	

n=3 for all sampling events with the exception of the 21 day retrieval from 102nd Street landfill where n=6

"." Compound was below the detection limit

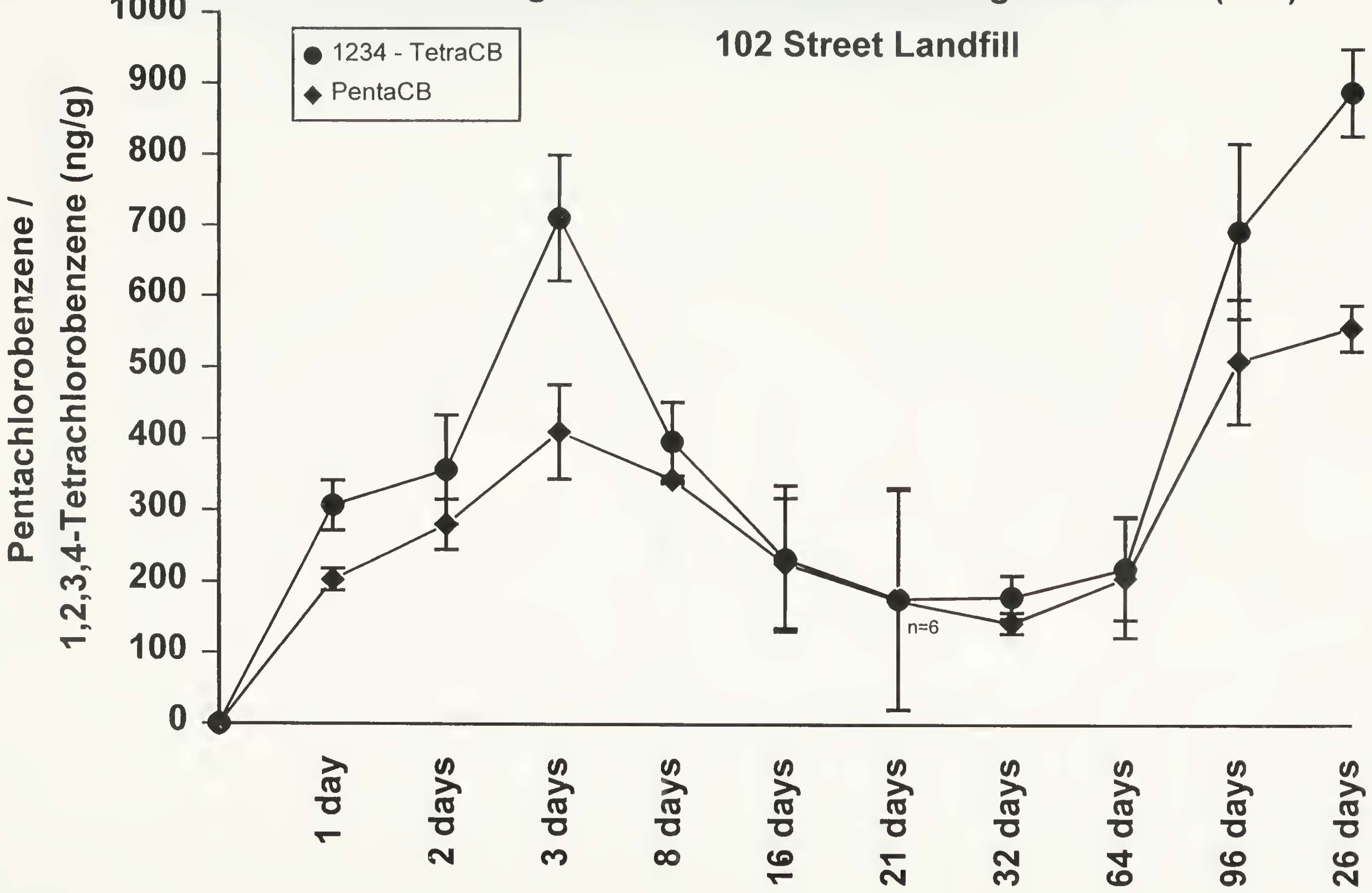


Figure 8: Contaminants in Caged Mussels (n=3)

102 Street Landfill

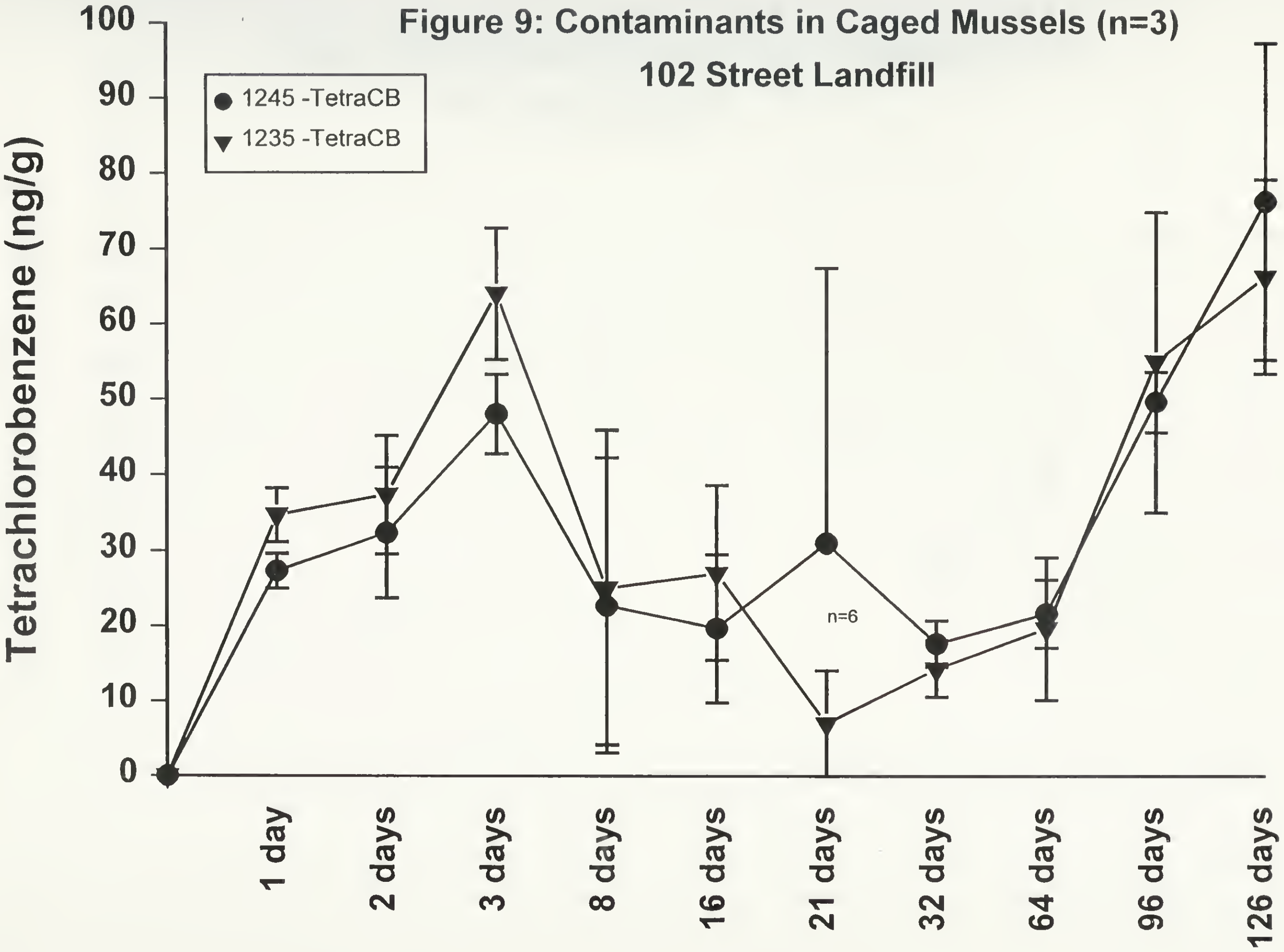
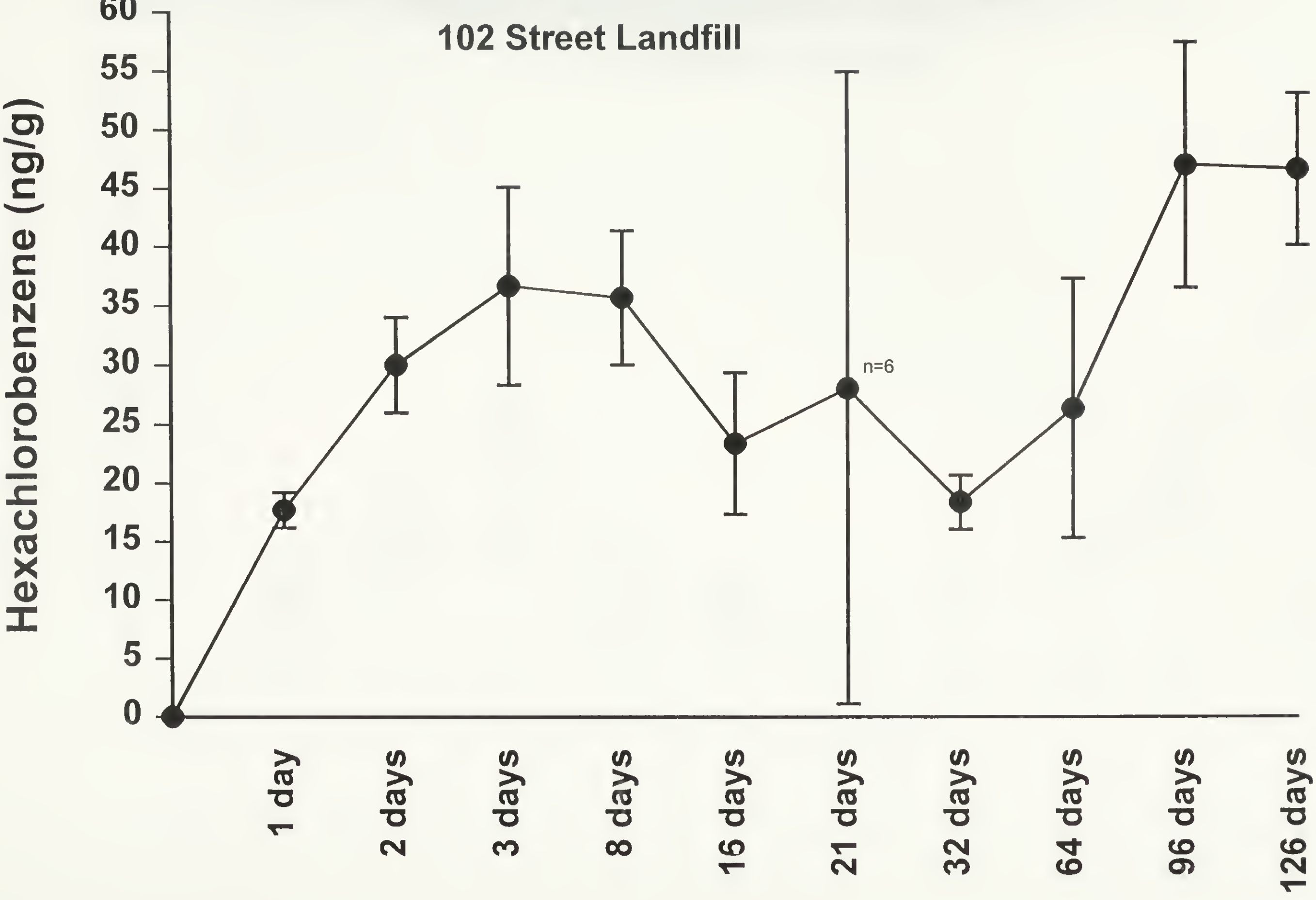


Figure 9: Contaminants in Caged Mussels (n=3)

102 Street Landfill

Figure 10: Contaminants in Caged Mussels (n=3)



102 Street Landfill

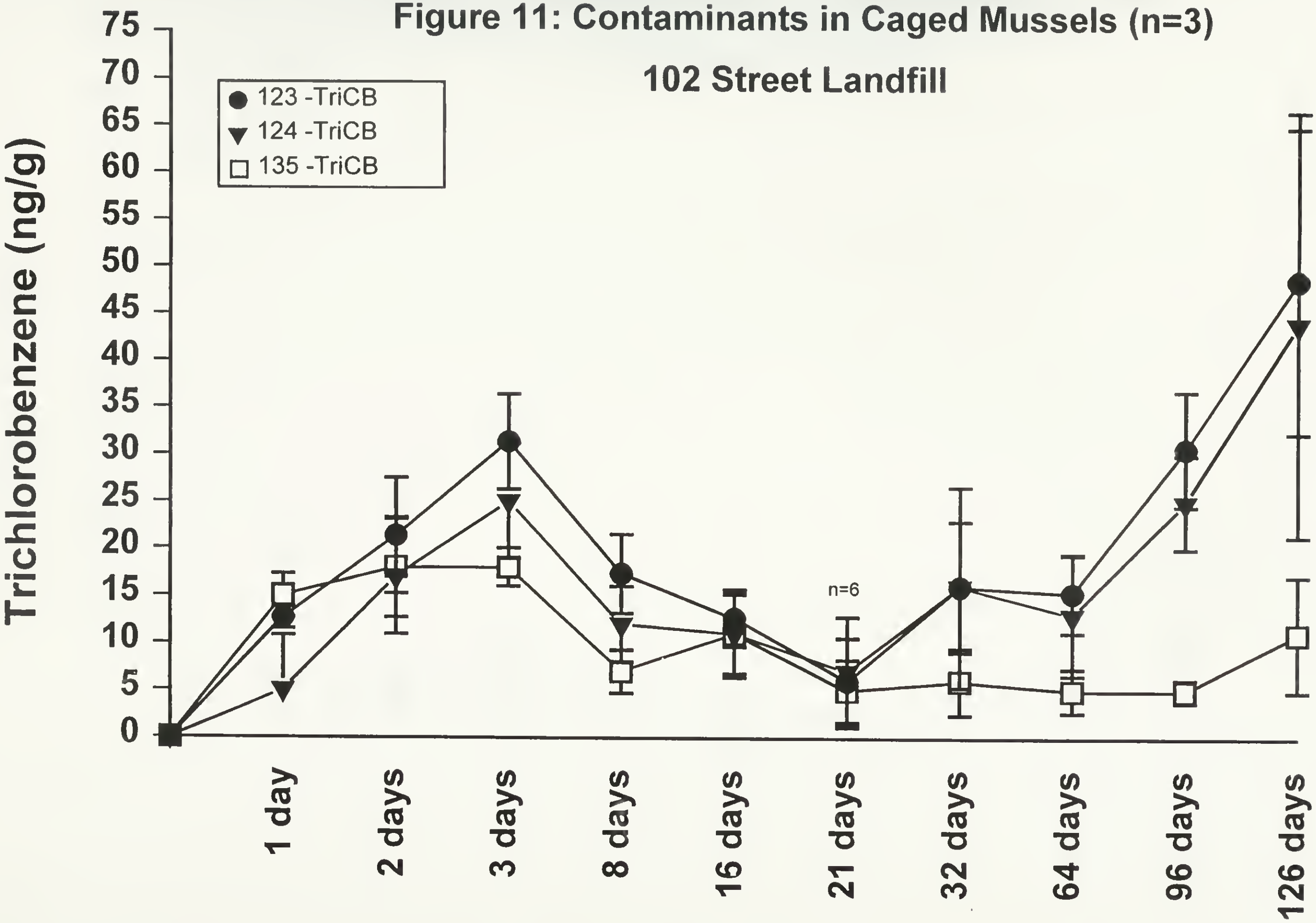
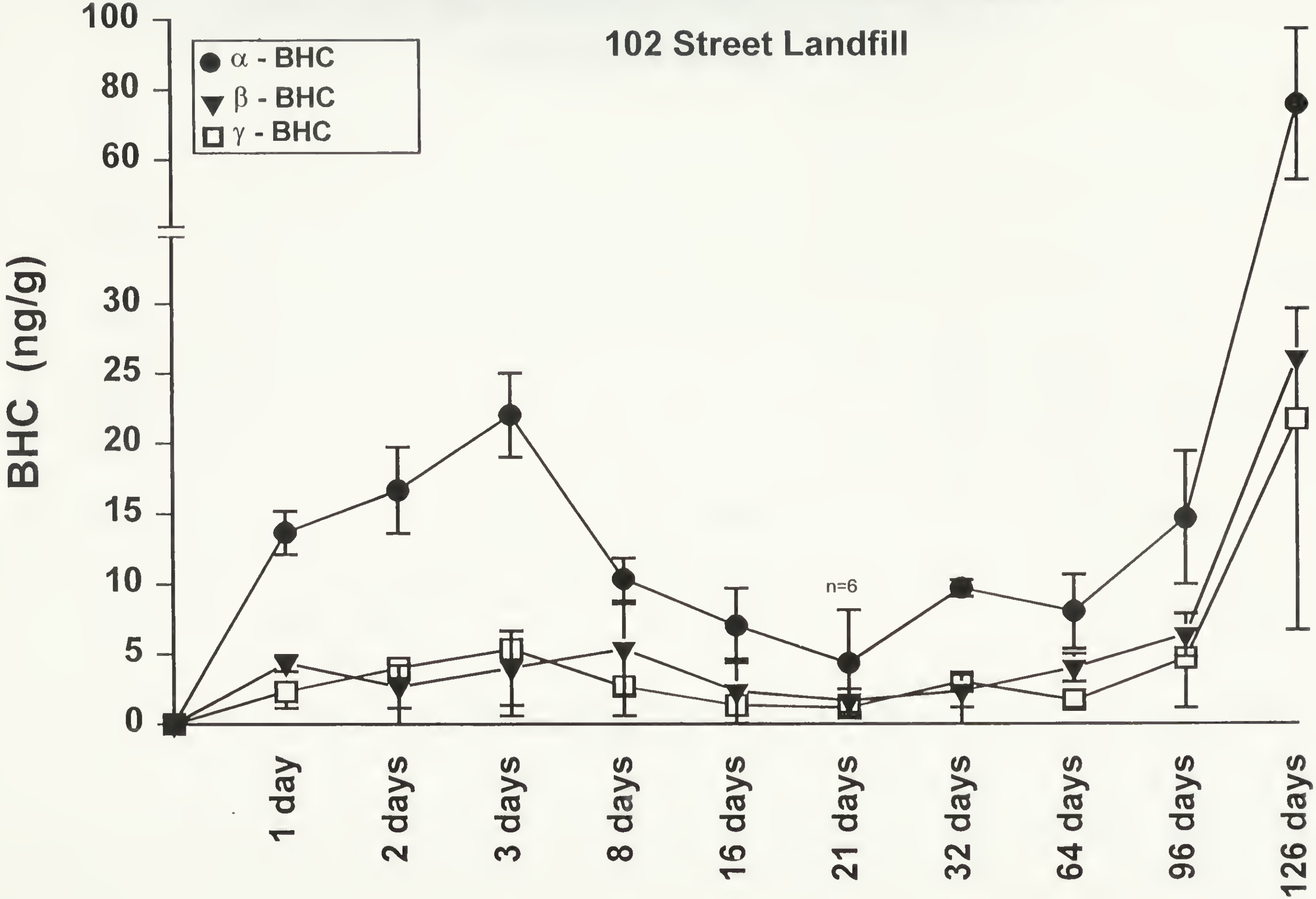


Figure 11: Contaminants in Caged Mussels (n=3)

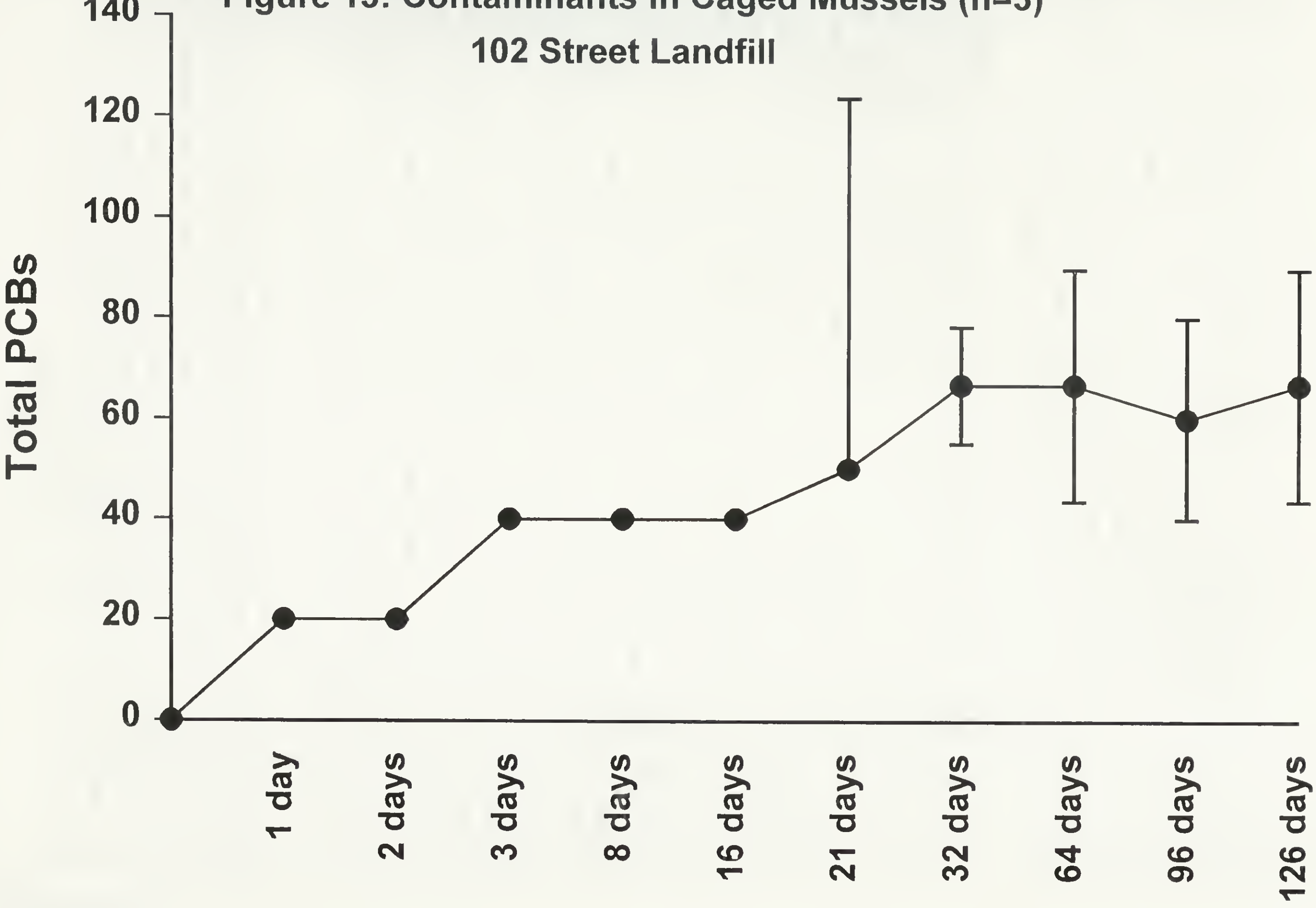
102 Street Landfill

Figure 12: Contaminants in Caged Mussels (n=3)



102 Street Landfill

Figure 13: Contaminants in Caged Mussels (n=3)
102 Street Landfill

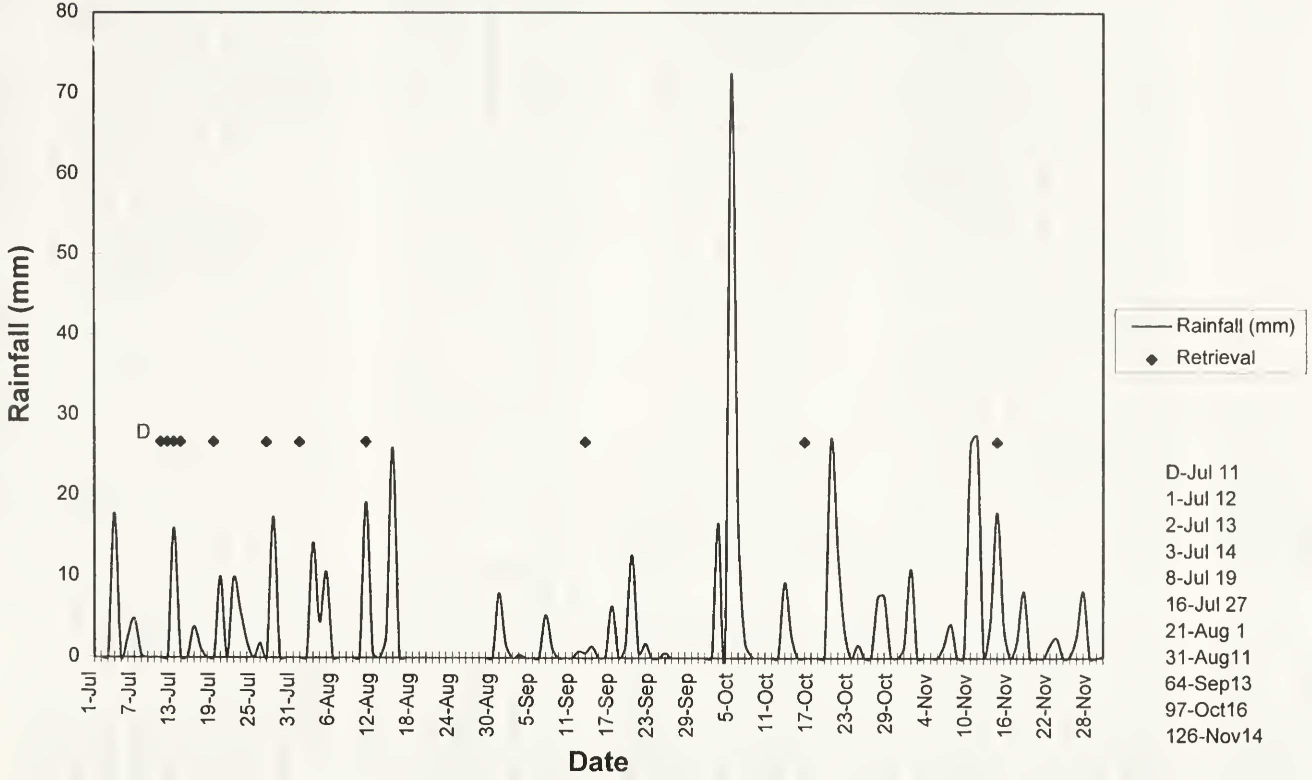


St. Clair River while octachlorostyrene (which has a high log K_{ow}) showed a pattern similar to the PCB uptake pattern in the Niagara River study (Muncaster *et al.* 1989). Rapid uptake of organochlorine compounds and PCB was also observed in a Niagara River survey using *Elliptio complanata* in 1980 (uptake was within two days), however,"steady state" or peak concentrations occurred more slowly between eight and sixteen days similar to the results in 1995. Depuration of PCBs from caged mussels placed in a relatively uncontaminated environment was also rapid initially (about 60% of the PCBs were lost within one day) followed by a much slower depuration rate from day two to fourteen (Kauss and Angelow 1988).

A plot of rainfall data for the Niagara Falls area (Environment Canada 1995) with mussel deployment/retrieval times suggests that contaminant uptake patterns may reflect contaminant inputs from the landfill or possibly other local non-point sources in response to rain events (Figure 14). The mussels responded quickly to surrounding environmental conditions by accumulating contaminants within the first 24 hours of exposure. Within 24 hours of a rain event (day three of exposure) there was another increase in tissue concentrations implying a change in water quality. One possible explanation is that the rain event caused a pulse of contaminants to enter the water column from the surrounding non-point sources, most likely the landfill. Mussels retrieved from day eight to day 64 did not show increases in contaminant concentrations because sampling either followed a minor rain event (for example day 16 and day 64), or mussels were sampled several days after large rain events which were followed by several days without any rainfall (for example day 21 and day 31). Changes in water quality from minor rain events may not have been sufficiently large to produce detectable changes in mussel tissue concentrations. Given the rapid response to environmental conditions the lack of rainfall for several days following large rain events may have provided sufficient time for the mussels to depurate contaminants before the retrieval date. Mussels are known to have the ability to excrete some contaminants relatively quickly when water concentrations decline (Muncaster *et al.* 1989). Fluctuating PAH tissue concentrations in mussels deployed in Dorchester Bay, Massachusetts were also attributed to runoff associated with major storm events. Interestingly, mussel tissue concentrations of PCBs and total DDT did not fluctuate over time but gradually increased during the same deployment period (Peven *et al.* 1996) similar to results for total PCBs in this survey.

Contaminant concentrations in mussel tissue increased on day 97 and continued to increase on day 126. Rainfall before both sampling events had been high. There was a total of 12.1 mm of rainfall for two days before the 97 day retrieval and a total of 59 mm for four days before the 126 day retrieval. There was also an extremely large rain event (72.4 mm) 10 days before the 97 day retrieval on October 5, 1995 which may have also had a large impact on local water quality. The upstream/downstream river monitoring data showed a large peak in contaminant loadings of chlorinated benzenes and BHC in water on October 5th and for chlorinated benzenes in

Figure 14: Rainfall (mm) in Niagara Falls, Ontario, 1995 and Caged Mussel Deployment/Retrieval Dates



D = Deployment date
1 to 126 = length of deployment in days.

suspended solids on October 12 at Niagara-on-the-Lake (K. Kuntz 1997, personal communication). These peaks may have been associated with the rain event on October 5th.

The pattern of contaminant uptake at the 102nd Street Landfill was not duplicated at the Occidental site. Contaminants were accumulated within the first 24 hours of exposure, however, concentrations of all contaminants detected in mussels at the Occidental site were low and relatively constant until day eight. There was a peak in tissue concentrations only at day 16 and day 21 and then concentrations decreased by day 31 (Figure 15 to 17). This pattern of accumulation was consistent for all compounds with detectable concentrations and implies a common source. The results suggest that the mussels were exposed to a contaminant pulse at some point between day eight and day 16 . The contaminant uptake pattern did not follow the pattern of rainfall events and was more consistent with an intermittent industrial point source discharge.

The parameters with the highest concentrations were 1,2,3,4-tetrachlorobenzene, pentachlorobenzene and hexachlorobenzene as well as 2,4,5 and 2,3,6-trichlorotoluene; two compounds which have always been associated with this outfall and which were not detected at the 102nd Street site. Other chlorinated benzenes typically present in caged mussels at this site at low concentrations were only detected on day 16, also consistent with the theory of a release of contaminants between day eight and day 16.

Without local water quality data, however, something inherent or unique to the environment at specific locations may have influenced contaminant uptake patterns and tissue concentrations (i.e. variations in the uptake or retention of contaminants as a function of water temperature or filtering activity). Measurements of water temperature at many near shore sites in the Niagara River in other studies suggested that the variability in temperature between sites would be low, thus eliminating this as a factor influencing between site differences (Kauss and Angelow 1988, Richman unpublished data).

It is unlikely that temporal uptake patterns or filtering rates were influenced by the breeding cycle of the mussels. Sampling and contaminant exposure were in the end of July and throughout the latter part of the summer and fall while the spawning period for *E. complanata* is in early summer (Matteson 1948). Mussel tissue weight did not change significantly throughout the study period at either site suggesting that this could not be a factor affecting tissue contaminant concentrations or uptake patterns (Figure 18 &19). As well, tissue weights did not differ between sites since mussels were specifically selected within a predefined size range, therefore, weight did not influence the results between stations. The ages of the mussel deployed at the two sites were unknown, however, since shell lengths were standardized to a

Figure 15: Contaminants in Caged Mussels (n=3)
Occidental Sewer 003

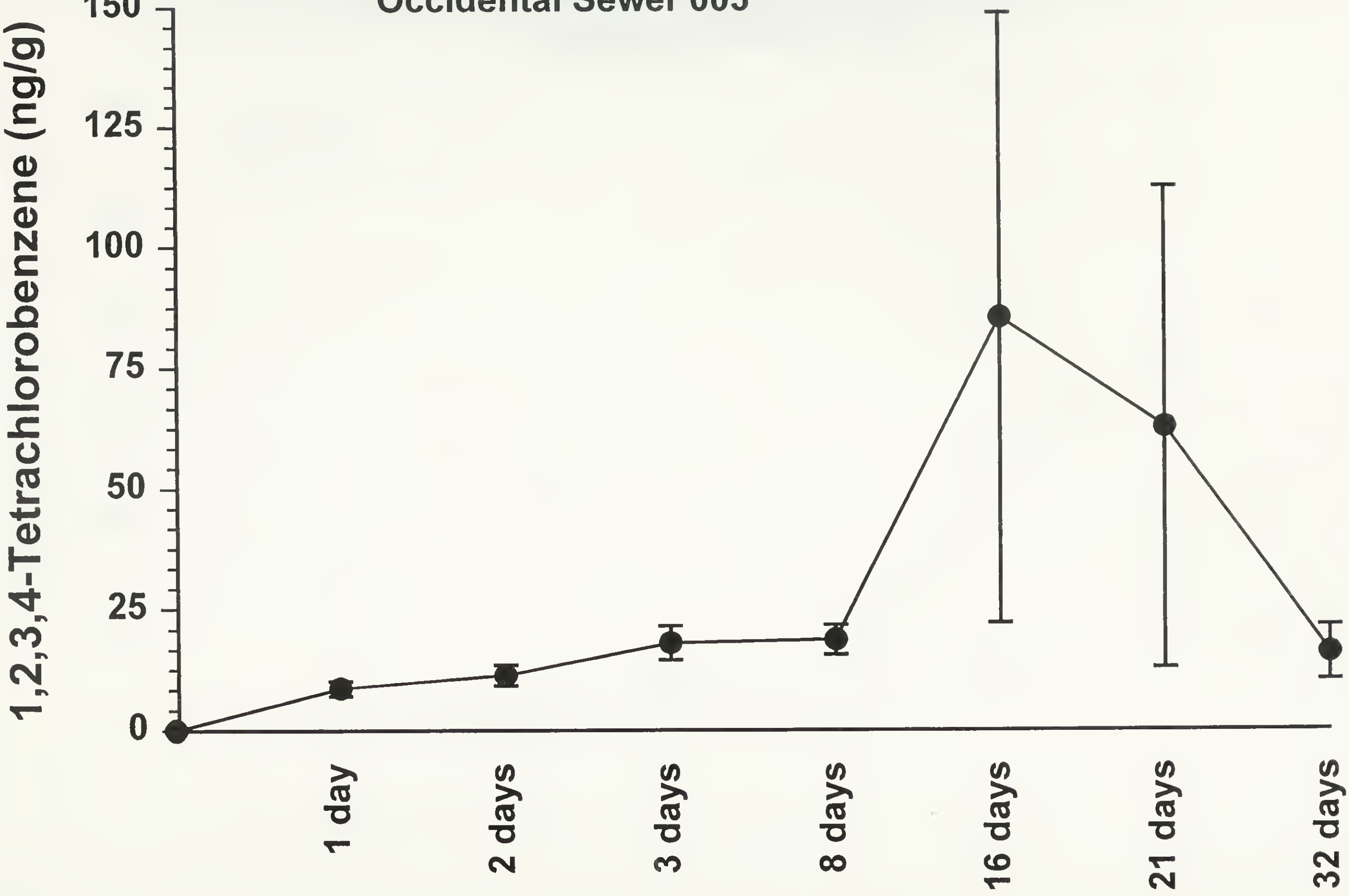


Figure 16: Contaminants in Caged Mussels (n=3)
Occidental Sewer 003

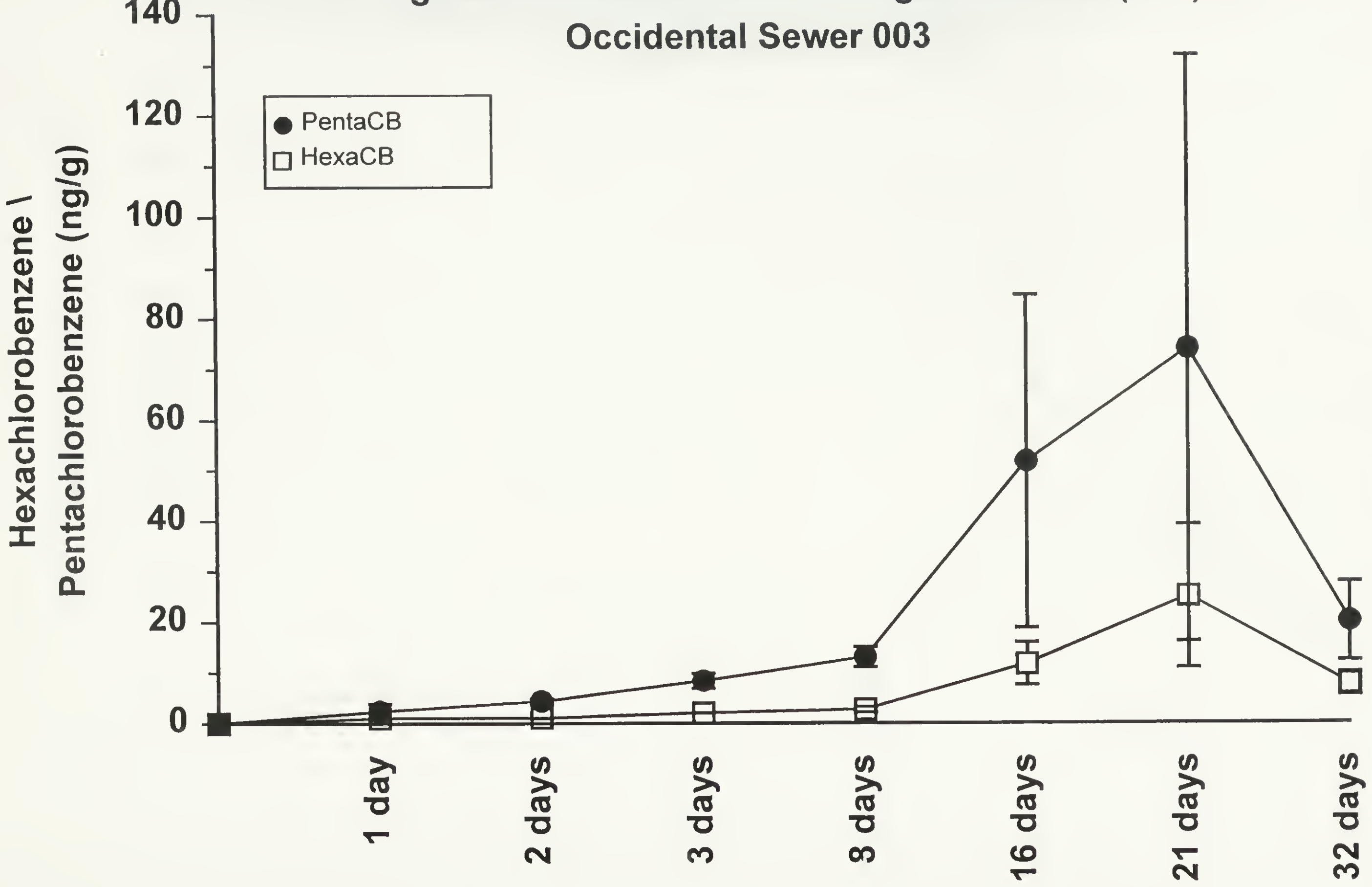
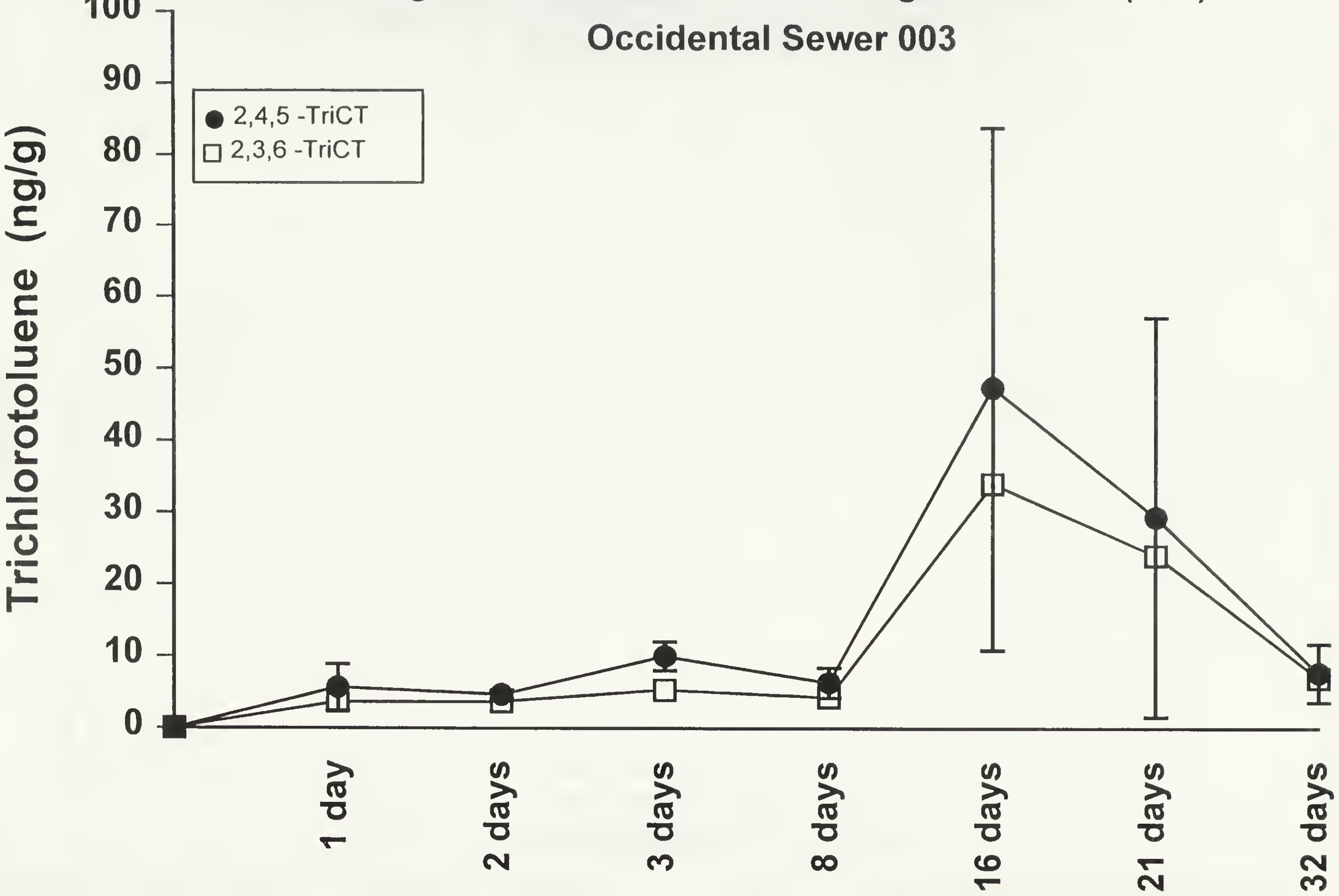


Figure 17: Contaminants in Caged Mussels (n=3)
Occidental Sewer 003



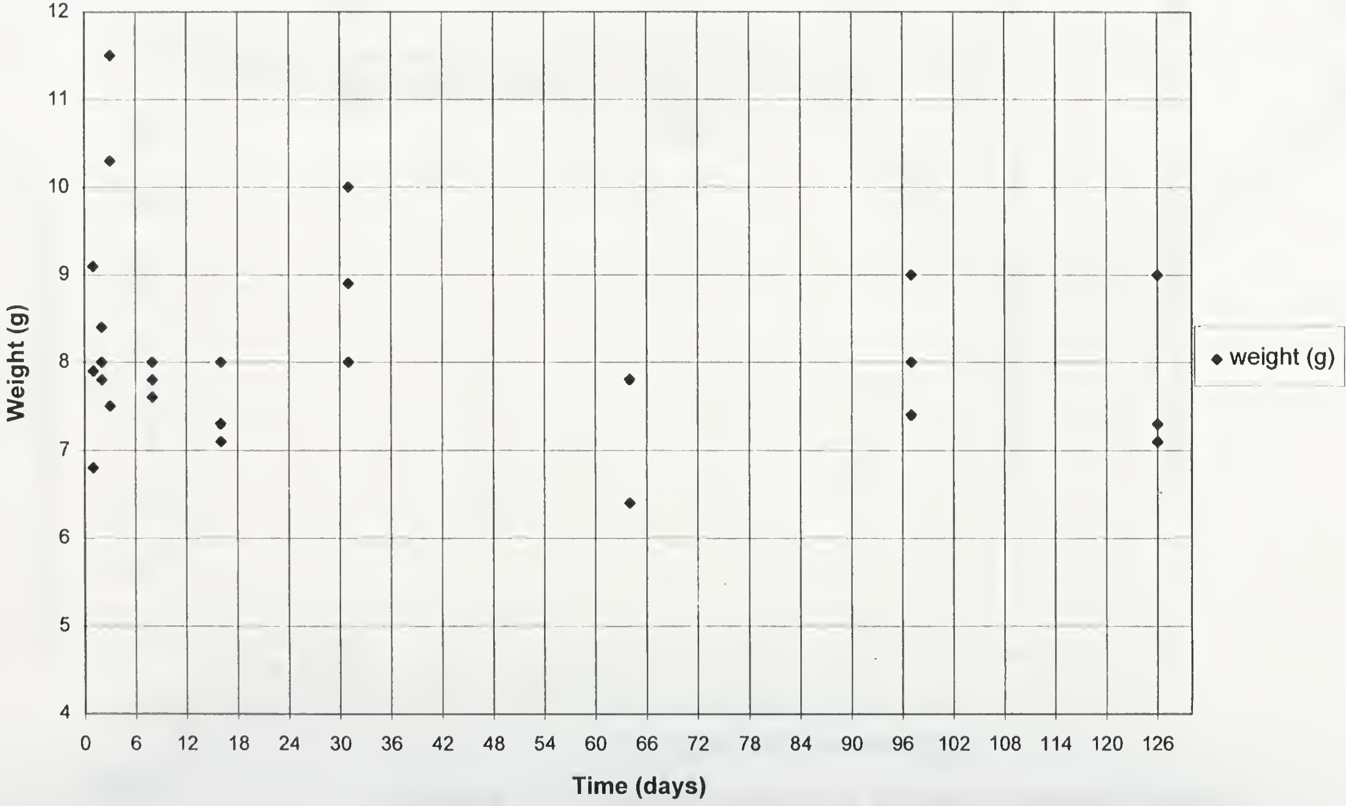


Figure 18: Tissue Weight vs Deployment Time
102 Street landfill

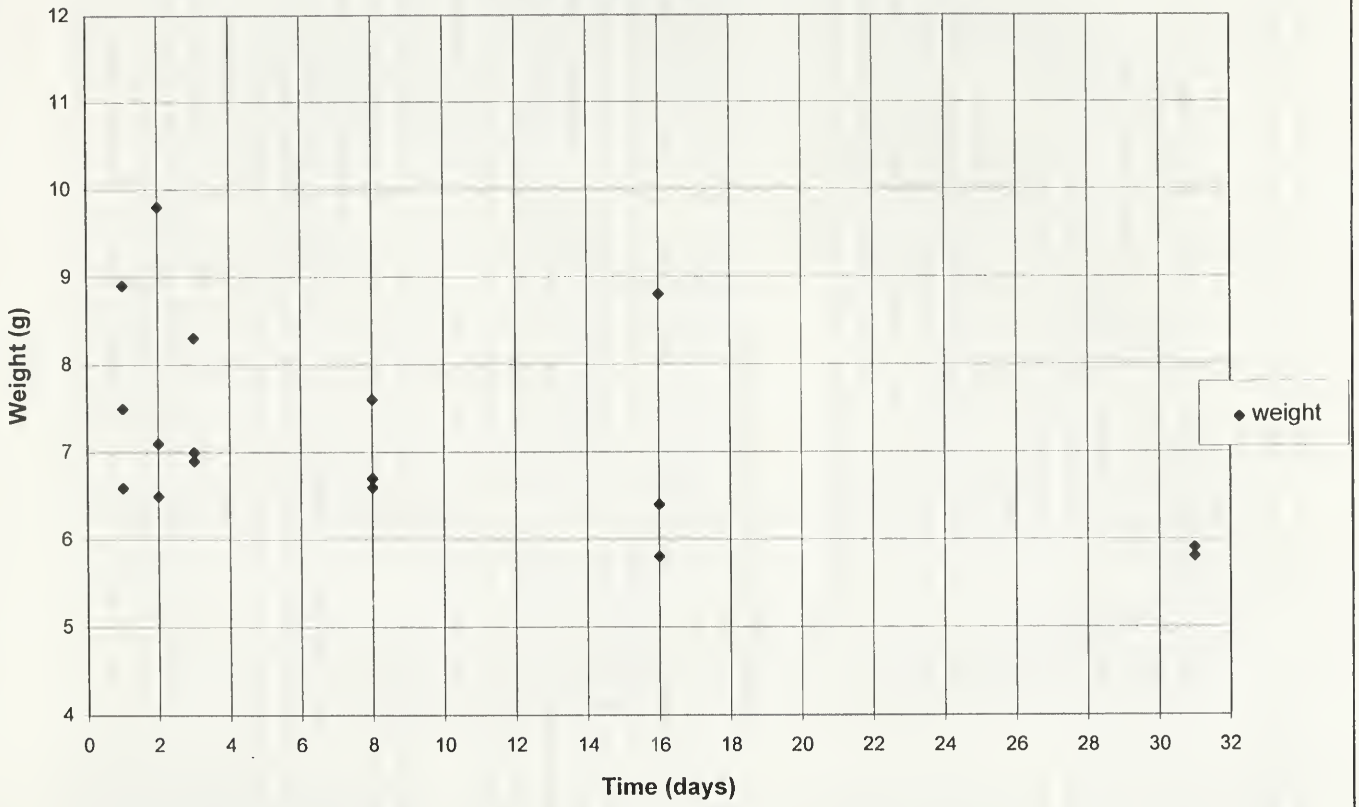


Figure 19: Tissue Weight vs Deployment Time
Occidental sewer 003

length of 6.5 to 7.2 cm there was an attempt to reduce variability due to age and size. Between site variations in age would be random since mussels were randomly selected for deployment at each station.

The fluctuations in tissue contaminant concentrations suggest that the water quality of the local sites was not constant. Although site specific water quality data were not collected for these sites, data from the Upstream/Downstream water quality monitoring program for July 1995 to December 1995 showed large fluctuations in weekly loadings of chlorinated benzenes to the Niagara River in water and suspended sediments (Kuntz personal communication). These fluctuations represent the dynamic nature of the many sources of these contaminants to the Niagara River. Concentrations of contaminants in mussels did not reach equilibrium or "steady state" at either of the sites with the possible exception of PCBs in mussels at 102nd Street. The use of the term “steady state” to describe contaminant tissue concentrations in mussels in an environment where water quality fluctuates is clearly inappropriate since mussels have the ability to quickly accumulate and depurate compounds in response to their changing environment with rates dependent on the compound (Mersch *et al*. 1996).

CONCLUSIONS AND RECOMMENDATIONS

The objective of the mussel biomonitoring program was to monitor the distribution of contaminants in the Niagara River and identify areas of concern for point and non point source investigations. The survey was designed specifically to monitor local near shore water quality rather than ambient river conditions where contaminants tend to be diluted by the massive flow of the river. It is difficult to determine the source of contaminants accumulated by the caged mussels because near shore water quality reflects an integration of upstream conditions, local point and non point sources and resuspended bottom sediment, however, the use of mussels upstream of suspected sources allows the identification of the upstream contribution of contaminants to the near shore water quality. Contaminants associated with specific sources tend to be accumulated by the mussels located at those sites, and the compounds are generally not found in mussels at sites immediately upstream. For example, the presence of BHC in mussel tissue, and the higher tissue concentrations of BHC at the 102nd Street site, were not observed consistently throughout the years of monitoring at other sites upstream or downstream of the 102nd Street Landfill. Since 1983 trichlorotoluene was almost exclusively (with few exceptions) accumulated by mussels at Occidental Sewer 003 and the other sewers associated with the Occidental facility. High concentrations of PAHs detected in mussels at the mouth of Two Mile Creek and the Pettit Flume (prior to remediation) were not detected at other sampling areas. The bioaccumulation patterns of dioxin and furan congeners in mussels at the Bloody Run Creek site were unique and different from the congener patterns found in mussels deployed at the Pettit Flume and 102nd Street Landfill.

Source identification can be more difficult for contaminants such as hexachlorobenzene, pentachlorobenzene and 1,2,3,4-tetrachlorobenzene with multiple sources and detection in mussels from many sites. Nevertheless, the highest tissue concentrations of these parameters were always present at the same stations (for example Pettit Flume, 102nd Street Landfill) and not at upstream stations between the Buffalo River and the Pettit Flume (for example Black Rock Canal, Tonawanda Channel, Two Mile Creek) or at stations between the Pettit Flume and 102nd Street Landfill such as Wheatfield and Gratwick Riverside Park. These results strongly suggested that the Pettit Flume and 102nd Street were two independent sources and caged mussels were successfully monitoring them as such.

The long term deployment study also provided strong evidence of the ability of caged mussels to be useful as site specific biomonitors. The unique contaminant uptake patterns at the two sites investigated, the difference in tissue concentrations between the two sites (concentrations of chlorobenzenes were at times 10 to 100 times higher in mussels at 102nd Street than in mussels at Occidental 003), and the difference in specific contaminants actually accumulated (for example trichlorotoluene), all point to the influence of local sources.

Results from other research using caged mussels showed that the contaminants were accumulated primarily from the water column rather than the sediment (Kauss and Hamdy 1991; Pugsley *et al.* 1985; Muncaster *et al.* 1989,1990). Muncaster *et al.* (1989;1990) did not find a significant difference in body burdens of pentachlorobenzene, hexachlorobenzene and octachlorostyrene in mussels in cages placed near the water surface, one metre above the sediment or on the sediment. Their tissue concentrations were assumed to reflect changing water quality rather than historic deposits of contaminants in the sediment. Previous studies on PAH contamination have also shown that the concentration of contaminants in tissue did not reflect the concentrations of these compounds in the sediment (Kauss and Hamdy 1991; Richman 1992).

The results from the mussel survey can also be compared with ongoing long-term trace contaminant monitoring using indigenous species (e.g. spottail shiners). There were three mussel monitoring stations in common with young of the year (common and/or spottail) shiner collection sites in 1995. These included Wheatfield, 102nd Street Landfill and Niagara-on-the-Lake. Common shiners collected from the 102nd Street site have consistently accumulated BHC and high concentrations of hexachlorobenzene and PCB since 1980 (Suns *et al.* 1991; OMOE unpublished data). These results were consistent with the data from mussel surveys since the 1980's. The shiners were not analysed for other chlorinated benzenes detected in mussels. Low concentrations of hexachlorobenzene and metabolites of DDT were present in shiners and mussels at the Wheatfield station, however, PCBs were only present in shiners. Similarly, at Niagara-on-the-Lake the shiners accumulated PCBs and metabolites of DDT while mussels only accumulated metabolites of DDT. PCB concentrations in mussels at these sites may be too low to be detected at OMOE detection limit of 20 ng/g.

The ability to integrate contaminants over time depends on pollution patterns which are characterized by contaminant discharge events that can vary in duration and intensity. Because mussel contaminant concentrations are changing in response to environmental conditions, variations in flow rates in industrial discharges, the complex interactions between uptake and depuration kinetics, as well as the time lag between exposure and tissue accumulation, a short term discharge of contaminants could escape monitoring even with regular sampling. The results of the biomonitoring program will, therefore, only provide a short term indicator of the presence or absence of bioavailable contaminants in the river. The results cannot be used to calculate contaminant loadings or long term contaminant discharge patterns. The identification of contaminant hot spots provides the opportunity for more detailed investigations and source identification to enable discussions on possible remedial actions.

Future Studies

The current design of the mussel biomonitoring program (21 day exposure) is useful for identifying contaminant source areas by providing information on the site specific presence and absence of contaminants in the tissue of deployed mussels. There are two recommendations concerning the design of the current survey.

1. Given the large within-station variability in mussel contaminant concentrations, future Niagara River Biomonitoring Study designs should consider the option of a single three mussel composite sample analysis per station rather than analysing three individual mussels.

2. The data collected provides qualitative information on the long term (i.e. data collected over the past 15 years) presence/absence of contaminants at individual stations. This study could still fulfill its objectives if it is carried out every three years rather than the present schedule of every two years. This new monitoring schedule would be consistent with other ongoing OMOE Great Lakes monitoring activities within the Environmental Monitoring and Reporting Branch.

In addition, the objective of future biomonitoring studies should be reviewed.

The long term deployment study using caged mussels produced results which suggest that there are fluctuating inputs of contaminants from non-point sources, and these inputs may be directly related to rain events. This theory is not new and has always been suspected of many non-point sources, however, there is a lack of information on temporal changes in pollution inputs from non point sources within the Niagara River and there is little information on the bioavailability of the contaminants, particularly from hazardous waste sites. This possible linkage of rainfall events with contaminant pulses suggests that the sampling designs using mussels in the future should be flexible to capture these contaminant inputs. The mussels accumulated most contaminants within 24 hours of exposure. Pulse events that occur any time after could be monitored to provide important information on temporal patterns of contaminant inputs.

A limitation of the current objective of the caged mussel study is the inability to use the data to calculate contaminant loadings or long term contaminant discharge patterns; therefore, consideration should be given to including a survey with the objective of investigating contaminant discharge patterns. Since frequent event specific sampling would be required, such a survey should focus on a few priority non-point sources.

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APPENDIX

APPENDIX A: Information on Station Location.

Station Name	Station Number	Latitude	Longitude
Canadian Sites			
Fort Erie at Robertson St.	203	42.92812	-78.91343
Frenchmans Creek (mouth)	20	42.94250	-78.92556
Millers Creek (mouth)	193	42.95250	-78.97556
Chippawa Channel	51	43.04956	-79.02050
NOTL	9	43.25385	-79.06016
US Sites			
Buffalo River (mouth)	196	42.87756	-78.88424
Black Rock Canal	91	42.89900	-78.90195
Tonawanda Channel (upstream of ck)	92	43.00872	-78.91330
Two Mile Creek (mouth)	197	43.01000	-78.90674
Pettit Flume (site B)	186	43.03429	-78.88557
Gratwick/Riverside Park	199	43.05712	-78.90470
Wheatfield	200	43.05750	-78.90806
102nd Street (upstream)	93	43.07118	-78.94502
102nd Street	22	43.07302	-78.95112
Cayuga Creek	31	43.08132	-78.96070
Storm Sewer C (upstream sewer 003)	43	43.07492	-79.00701
Occidental's S. 003	42	43.07499	-79.00715
Storm Sewer	40	43.07525	-79.00802
Occidental S. 002	90	43.07639	-78.01278
Gill Creek (upstream)	15-22	43.08454	-79.02373
Bloody Run Creek	17	43.13877	-79.04347

APPENDIX B Concentrations of organochlorine pesticides and total PCBs in caged mussels introduced to the Niagara River, 1995. <W. no measurable response. <T measurable trace amount, interpret with caution.

BOW	STN.	STN	DATE	TIME	SAMP	FIELD	Aldrin		a-BHC		b-BHC		g-BHC		a-chlordane		g-chlordane		heptachlor		mirex		o'p-DDT		PCB (total)		photomirex		p'p-DDD		p'p-DDE		p'p-DDT		toxaphene	
	TYP	No.	YYMMDD		DEPTH	SAMPLE	NG/G W		NG/G W		NG/G W		NG/G W		NG/G W		NG/G W		NG/G W		NG/G W		NG/G W		NG/G W		NG/G W		NG/G W		NG/G W		NG/G W		NG/G W	
					(m.)	NUMBER		RMK		RMK		RMK		RMK		RMK		RMK		RMK		RMK		RMK		RMK		RMK		RMK		RMK		RMK		RMK
5	2	22	950801	1311	0.5	GL573863	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	200	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	22	950801	1311	0.5	GL573864	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	22	950801	1311	0.5	GL573865	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	22	950801	1311	0.5		1	<=W	9		2	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	4		5	<=W	200	<=W
5	2	22	950801	1311	0.5		1	<=W	8		3	<=W	2	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	2		5	<=W	200	<=W
5	2	22	950801	1311	0.5		1	<=W	6		2	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	2		5	<=W	200	<=W
5	2	40	950801	1123	0.5	GL573854	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	40	950801	1123	0.5	GL573855	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	40	950801	1123	0.5	GL573856	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	42	950801	1137	1	GL573857	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	42	950801	1137	1	GL573858	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	42	950801	1137	1	GL573859	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	43	950801	1151	0.3	GL573860	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	16		5	<=W	200	<=W
5	2	43	950801	1151	0.3	GL573861	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	40	P40	4	<=W	5	<=W	17		5	<=W	200	<=W
5	2	43	950801	1151	0.3	GL573862	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	260	P40	4	<=W	5	<=W	4	<T	5	<=W	200	<=W
5	2	43	950801	1151	0.3		1	<=W	2	<=W	11	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	6		5	<=W	200	<=W
5	2	51	950803	1113	2	GL573899	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	51	950803	1113	2	GL573900	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	51	950803	1113	2	GL573901	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	90	950801	1115	0.5	GL573851	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	6	<T	5	<=W	200	<=W
5	2	90	950801	1115	0.5	GL573852	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	40	P84	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	90	950801	1115	0.5	GL573853	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	60	P84	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	91	950802	1116	0.5	GL573881	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	4	<T	5	<=W	200	<=W
5	2	91	950802	1116	0.5	GL573882	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	91	950802	1116	0.5	GL573883	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	92	950802	1000	2	GL573902	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	92	950802	1000	2	GL573903	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	92	950802	1000	2	GL573904	1	<=W	11		4	<T	3	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	240	P40	4	<=W	5	<=W	5	<T	5	<=W	200	<=W
5	2	93	950802	820	1	GL573866	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	4	<T	5	<=W	200	<=W
5	2	93	950802	820	1	GL573867	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	5	<T	5	<=W	200	<=W
5	2	93	950802	820	1	GL573868	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	3	<T	5	<=W	200	<=W
5	2	186	950802	915	0.5	GL573875	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	186	950802	915	0.5	GL573876	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	4	<T	5	<=W	200	<=W
5	2	186	950802	915	0.5	GL573877	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	6	<T	5	<=W	200	<=W
5	2	193	950803	1044	0.7	GL573896	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	9	<T	5	<=W	200	<=W
5	2	193	950803	1044	0.7	GL573897	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	5	<T	5	<=W	200	<=W
5	2	193	950803	1044	0.7	GL573898	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	196	950802	1152	5	GL573884	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	196	950802	1152	5	GL573885	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	196	950802	1152	5	GL573886	1	<=W	18		10		1	<=W	4	<T	4	<T	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	197	950802	1041	1	GL573878	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	5	<T	5	<=W	200	<=W
5	2	197	950802	1041	1	GL573879	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	197	950802	1041	1	GL573880	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	199	950802	855	1	GL573872	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	14		5	<=W	200	<=W
5	2	199	950802	855	1	GL573873	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	4	<T	5	<=W	200	<=W
5	2	199	950802	855	1	GL573874	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	199	950802	855	1		1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	199	950802	855	1		1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	199	950802	855	1		1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	200	950802	840	1	GL573869	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	3	<T	5	<=W	200	<=W
5	2	200	950802	840	1	GL573870	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	4	<T	5	<=W	200	<=W
5	2	200	950802	840	1	GL573871	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	3	<T	5	<=W	200	<=W
5	2	203	950803	930	1	GL573890	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	203	950803	930	1	GL573891	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	2	203	950803	930	1	GL573892	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	15	20	950803	1013	0.3	GL573893	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	10	<T	19		5	<=W	200	<=W
5	15	20	950803	1013	0.3	GL573894	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	8	<T	5	<=W	200	<=W
5	15	20	950803	1013	0.3	GL573895	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	5	<T	5	<=W	200	<=W
5	15	22	950801	1021	0.2	GL573848	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	120	P84	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	15	22	950801	1021	0.2	GL573849	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	360	P84	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	15	22	950801	1021	0.2	GL573850	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	120	P84	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
5	15	31	950803	800	1	GL573887	1	<=W	26		15		3	<T	6	<T	8	<T	1	<=W	5	<=W	5	<=W	120	P40	4	<=W	10	<T	1	<=W	5	<=W	200	<=W
5	15	31	950803	800	1	GL573888	1	<=W	25		17		2	<T	4	<T	6	<T	1	<=W	5	<=W	5	<=W	80	P40	4	<=W	10	<T	1	<=W	5	<=W	200	<=W
5	15	31	950803	800	1	GL573889	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
11	2	9	950801	724	0.5	GL573842	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
11	2	9	950801	724	0.5	GL573843	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
11	2	9	950801	724	0.5	GL573844	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	4	<T	5	<=W	200	<=W
11	2	17	950801	828	0.1	GL573845	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
11	2	17	950801	828	0.1	GL573846	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
11	2	17	950801	828	0.1	GL573847	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W

APPENDIX B: Concentrations of chlorinated benzenes (CB) and industrial compounds in caged mussels introduced to the Niagara River, 1995. <= . no measurable response. <T.measurable trace amount, interpret with caution

STN No.	DATE YYMMDD	TIME	SMPLE DEPTH (m.)	FIELD SAMPLE NUMBER	hexaCB NG/G W	RMK	hexachloro-ethene NG/G W	RMK	octacloro-styrene NG/G W	RMK	pentaCB NG/G W	RMK	236-trichloro toluene NG/G W	RMK	245-trichloro toluene NG/G W	RMK	26-dichloro benzyl Cl NG/G W	RMK	123-triCB NG/G W	RMK	1234-tetra CB NG/G W	RMK	1235-tetra CB NG/G W	RMK	124-triCB NG/G W	RMK	1245-terta CB NG/G W	RMK	135-triCB NG/G W	RMK
22	950801	1311	0.5	GL573863	74		1	<=W	2	<T	400		1	<=W	5	<T	1	<=W	2	<=W	400		1	<=W	2	<=W	1	<=W	2	<=W
22	950801	1311	0.5	GL573864	4	<T	1	<=W	1	<=W	2	<T	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
22	950801	1311	0.5	GL573865	4	<T	1	<=W	1	<=W	2	<T	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
22	950801	1311	0.5		43		1	<=W	1	<=W	263		1	<=W	1	<=W	1	<=W	11		264		16		14		51		9	
22	950801	1311	0.5		21		1	<=W	1	<=W	206		1	<=W	1	<=W	1	<=W	11		215		14		13		43		8	
22	950801	1311	0.5		20		1	<=W	1	<=W	175		1	<=W	1	<=W	1	<=W	9		179		11		10		89		6	
40	950801	1123	0.5	GL573854	7	<T	1	<=W	1	<=W	12		1	<=W	1	<=W	1	<=W	2	<=W	13		1	<=W	2	<=W	1	<=W	2	<=W
40	950801	1123	0.5	GL573855	13		1	<=W	1	<=W	19		1	<=W	1	<=W	1	<=W	2	<=W	17		1	<=W	2	<=W	1	<=W	2	<=W
40	950801	1123	0.5	GL573856	15		1	<=W	1	<=W	20		6	<T	7	<T	1	<=W	2	<=W	20		1	<=W	2	<=W	1	<=W	2	<=W
42	950801	1137	1	GL573857	23		1	<=W	1	<=W	50		12		6	<T	1	<=W	2	<=W	30		1	<=W	2	<=W	1	<=W	2	<=W
42	950801	1137	1	GL573858	12		1	<=W	1	<=W	32		14		22		1	<=W	2	<=W	38		1	<=W	2	<=W	1	<=W	2	<=W
42	950801	1137	1	GL573859	40		1	<=W	1	<=W	140		46		60		1	<=W	2	<=W	120		1	<=W	2	<=W	1	<=W	2	<=W
43	950801	1151	0.3	GL573860	250		1	<=W	42		75		1	<=W	5	<T	1	<=W	2	<=W	20		1	<=W	2	<=W	1	<=W	2	<=W
43	950801	1151	0.3	GL573861	190		1	<=W	29		54		1	<=W	4	<T	1	<=W	2	<=W	15		1	<=W	2	<=W	1	<=W	2	<=W
43	950801	1151	0.3	GL573862	90		1	<=W	1	<=W	580		1	<=W	7	<T	1	<=W	2	<=W	480		1	<=W	2	<=W	1	<=W	2	<=W
43	950801	1151	0.3		98		1	<=W	14		35		1	<=W	1	<=W	1	<=W	2	<=W	13		1	<=W	2	<=W	1	<=W	2	<=W
51	950803	1113	2	GL573899	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
51	950803	1113	2	GL573900	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
51	950803	1113	2	GL573901	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
90	950801	1115	0.5	GL573851	4	<T	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	8	<T	1	<=W	2	<=W	1	<=W	2	<=W
90	950801	1115	0.5	GL573852	24		1	<=W	2	<T	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	15		1	<=W	2	<=W	1	<=W	2	<=W
90	950801	1115	0.5	GL573853	10		1	<=W	2	<T	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	18		1	<=W	2	<=W	1	<=W	2	<=W
91	950802	1116	0.5	GL573881	1	<=W	21		1	<=W	2	<T	1	<=W	12		1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
91	950802	1116	0.5	GL573882	1	<=W	41		1	<=W	3	<T	1	<=W	18		1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
91	950802	1116	0.5	GL573883	1	<=W	1	<=W	1	<=W	3	<T	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
91	950802	1116	0.5		1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
91	950802	1116	0.5		1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
91	950802	1116	0.5		1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
92	950802	1000	2	GL573902	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
92	950802	1000	2	GL573903	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
92	950802	1000	2	GL573904	62		1	<=W	1	<=W	380		1	<=W	1	<=W	1	<=W	16	<T	310		30		30		54		16	<T
93	950802	820	1	GL573866	4	<T	1	<=W	1	<=W	3	<T	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
93	950802	820	1	GL573867	4	<T	1	<=W	1	<=W	3	<T	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
93	950802	820	1	GL573868	3	<T	1	<=W	1	<=W	2	<T	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
186	950802	915	0.5	GL573875	32		1	<=W	1	<=W	33		1	<=W	1	<=W	1	<=W	2	<=W	15		9	<T	2	<=W	9	<T	2	<=W
186	950802	915	0.5	GL573876	72		1	<=W	1	<=W	76		1	<=W	1	<=W	1	<=W	2	<=W	36		28		2	<=W	20		2	<=W
186	950802	915	0.5	GL573877	5	<T	1	<=W	1	<=W	3	<T	1	<=W	1	<=W	1	<=W	2	<=W	3	<T	1	<=W	2	<=W	1	<=W	2	<=W
193	950803	1044	0.7	GL573896	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
193	950803	1044	0.7	GL573897	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
193	950803	1044	0.7	GL573898	7	<T	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
193	950803	1044	0.7		1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
193	950803	1044	0.7		1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
193	950803	1044	0.7		1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
196	950802	1152	5	GL573884	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
196	950802	1152	5	GL573885	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
196	950802	1152	5	GL573886	5	<T	1	<=W	1	<=W	21		1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
196	950802	1152	5		1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
196	950802	1152	5		1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
196	950802	1152	5		1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	3		1	<=W	1	<=W	3		1	<=W	2	<=W
197	950802	1041	1	GL573878	5	<T	1	<=W	1	<=W	3	<T	1	<=W	1	<=W	1	<=W	2	<=W	2	<T	1	<=W	2	<=W	1	<=W	2	<=W
197	950802	1041	1	GL573879	4	<T	1	<=W	1	<=W	3	<T	1	<=W	1	<=W	1	<=W	2	<=W	2	<T	1	<=W	2	<=W	1	<=W	2	<=W
197	950802	1041	1	GL573880	1	<=W	1	<=W	1	<=W	2	<T	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
199	950802	855	1	GL573872	250		1	<=W	60		78		1	<=W	1	<=W	1	<=W	2	<=W	22		4	<T	2	<=W	5	<T	2	<=W
199	950802	855	1	GL573873	4	<T	1	<=W	1	<=W	2	<T	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
199	950802	855	1	GL573874	81		1	<=W	1	<=W	76		1	<=W	1	<=W	1	<=W	2	<=W	34		19		2	<=W	15		2	<=W
199	950802	855	1		1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
199	950802	855	1		3		1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
199	950802	855	1		2		1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
200	950802	840	1	GL573869	8	<T	1	<=W	1	<=W	3	<T	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
200	950802	840	1	GL573870	4	<T	1	<=W	1	<=W	3	<T	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
200	950802	840	1	GL573871	8	<T	1	<=W	1	<=W	3	<T	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
203	950803	930	1	GL573890	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
203	950803	930	1	GL573891	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
203	950803	930	1	GL573892	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
20	950803	1013	0.3	GL573893	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
20	950803	1013	0.3	GL573894	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
20	950803	1013	0.3	GL573895	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
20	950803	1013	0.3		1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
20	950803	1013	0.3		1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
20	950803	1013	0.3		1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
22	950801	1021	0.2	GL573848	2	<T	1	<=W	2	<T	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
22	950801	1021	0.2	GL573849	4	<T	1	<=W	5	<T	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
22	950801	1021	0.2	GL573850	2	<T	1	<=W	3	<T	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
31	950803	800	1	GL573887	5	<T	15		1	<=W	23		1	<=W	8	<T	1	<=W	2	<=W	16		1	<=W	2	<=W	1	<=W	2	<=W
31	950803	800	1	GL573888	5	<T	1	<=W	1	<=W	25		1	<=W	8	<T	1	<=W	2	<=W	17		1	<=W	2	<=W	1	<=W	2	<=W
31	950803	800	1	GL573889	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
9	950801	724	0.5	GL573842	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
9	950801	724	0.5	GL573843	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
9	950801	724	0.5	GL573844	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
17	950801	828	0.1	GL573845	47		1	<=W	1	<=W	22		1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
17	950801	828	0.1	GL573846	44		1	<=W	2	<T	30		1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W

APPENDIX C: Concentrations of organochlorine pesticides and total PCBs in caged mussels introduced to the Niagara River, 1995. <W: no measurable response. <T: measurable trace amount, interpret with caution.

	Long Term Deployment																															
STN	DATE		Aldrin		a-BHC		b-BHC		g-BHC		a-chlordane		g-chlordane		heptachlor		mirex		o'p-DDT		PCB (total)		photomirex		p'p-DDD		p'p-DDE		p'p-DDT		toxaphene	
		Deployment																														
	YYMMDD		ng/g		ng/g		ng/g		ng/g		ng/g		ng/g		ng/g		ng/g		ng/g		ng/g		ng/g		ng/g		ng/g		ng/g		ng/g	
102nd St.	950712	1 day	1	<=W	14		4	<T	3	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950712		1	<=W	15		4	<T	3	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	3	<T	5	<=W	200	<=W
	950712		1	<=W	12		5	<T	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950713	2 days	1	<=W	20		4	<T	4	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950713		1	<=W	16		3	<T	4	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950713		1	<=W	14		1	<=W	4	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950714	3 days	1	<=W	22		1	<=W	5	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	40	P40	4	<=W	5	<=W	6	<T	5	<=W	200	<=W
	950714		1	<=W	19		5	<T	5	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950714		1	<=W	25		8	<T	8	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950719	8 days	1	<=W	12		4	<T	3	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950719		1	<=W	9	<T	9	<T	2	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950719		1	<=W	10		3	<T	3	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950727	16 days	1	<=W	8	<T	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950727		1	<=W	10		5	<T	2	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950727		1	<=W	5	<T	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950801	21 days	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	200	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950801		1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950801		1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950801		1	<=W	9	<T	2	<T	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	4	<=W	5	<=W	200	<=W
	950801		1	<=W	8	<T	3	<T	2	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	2	<=W	5	<=W	200	<=W
	950801		1	<=W	8	<T	2	<T	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	2	<=W	5	<=W	200	<=W
	950811	31 days	1	<=W	10		3	<T	3	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	80	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950811		1	<=W	9	<T	1	<=W	3	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	80	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950811		1	<=W	10		3	<T	3	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	80	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950913	64 days	1	<=W	11		4	<T	3	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	80	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950913		1	<=W	6	<T	3	<T	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950913		1	<=W	7	<T	5	<T	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	80	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	951016	97 days	1	<=W	11		8	<T	4	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	80	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	951016		1	<=W	13		5	<T	4	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	951016		1	<=W	20		8	<T	6	<T	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	80	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	951114	126 days	1	<=W	100		27		29		2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	80	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	951114		1	<=W	59		29		18		2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	80	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	951114		1	<=W	68		22		20		2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	40	P40	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
Occ. 003	950712	1 day	1	<=W	5	<T	3	<T	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950712		1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950712		1	<=W	6	<T	3	<T	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950713	2 days	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950713		1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950713		1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950714	3 days	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950714		1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950714		1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950719	8 days	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950719		1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950719		1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950727	16 days	1	<=W	5	<T	5	<T	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950727		1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950727		1	<=W	5	<T	4	<T	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950801	21 days	1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950801		1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950801		1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950811	31 days	1	<=W	3	<T	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950811		1	<=W	1	<=W	1	<=W	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W
	950811		1	<=W	3	<T	4	<T	1	<=W	2	<=W	2	<=W	1	<=W	5	<=W	5	<=W	20	<=W	4	<=W	5	<=W	1	<=W	5	<=W	200	<=W

APPENDIX C: Concentrations of chlorinated benzenes (CB) and industrial compounds in caged mussels introduced to the Niagara River, 1995. <MD.method detection <= W. no measurable response. <T measurable trace amount, interpret with caution

Long Term Deployment

STN	DATE YYMMDD	Deployment	HCBD ng/g		hexeCB ng/g		hexachloro-ethane ng/g		octacloro-styrene ng/g		pentaCB ng/g		236-trichloro toluene ng/g		245-trichloro toluene ng/g		26-dichloro benzyl Cl ng/g		123-triCB ng/g		1234-tetra CB ng/g		1235-tetra CB ng/g		124-triCB ng/g		1245-terta CB ng/g		135-triCB ng/g	
102nd St	950712	1 day	1	<MD	16		1	<=W	1	<=W	220		1	<=W	1	<=W	1	<=W	14	<T	340		38		2	<=W	30		16	<T
	950712		1	<MD	18		1	<=W	1	<=W	200		1	<=W	1	<=W	1	<=W	12	<T	310		35		12	<T	26		16	<T
	950712		1	<MD	19		1	<=W	1	<=W	190		1	<=W	1	<=W	1	<=W	12	<T	270		31		2	<=W	26		12	<T
	950713	2 days	1	<MD	30		1	<=W	1	<=W	300		1	<=W	1	<=W	1	<=W	28		440		46		24		34		24	
	950713		1	<MD	34		1	<=W	1	<=W	300		1	<=W	1	<=W	1	<=W	20		340		35		16	<T	40		16	<T
	950713		1	<MD	26		1	<=W	1	<=W	240		1	<=W	1	<=W	1	<=W	16	<T	290		31		12	<T	23		14	<T
	950714	3 days	1	<MD	41		1	<=W	1	<=W	400		1	<=W	1	<=W	1	<=W	26		640		58		24		44		16	<T
	950714		1	<MD	27		1	<=W	1	<=W	350		1	<=W	1	<=W	1	<=W	32		680		60		20		46		18	<T
	950714		1	<MD	42		1	<=W	1	<=W	480		1	<=W	1	<=W	1	<=W	36		810		74		32		54		20	
	950719	8 days	1	<MD	42		1	<=W	1	<=W	350		1	<=W	1	<=W	1	<=W	22		450		36		16	<T	39		8	<T
	950719		1	<MD	34		1	<=W	1	<=W	340		1	<=W	1	<=W	1	<=W	14	<T	340		1	<=W	8	<T	1	<=W	4	<T
	950719		1	<MD	31		1	<=W	1	<=W	340		1	<=W	1	<=W	1	<=W	16		400		38		12		28		8	
	950727	16 days	1	<MD	17		1	<=W	1	<=W	160		1	<=W	1	<=W	1	<=W	10	<T	160		18		10	<T	13		8	<T
	950727		1	<MD	29		1	<=W	1	<=W	330		1	<=W	1	<=W	1	<=W	16	<T	350		40		16	<T	31		16	<T
	950727		1	<MD	24		1	<=W	1	<=W	190		1	<=W	1	<=W	1	<=W	12	<T	190		23		8	<T	15		8	<T
	950801	21 days	no data		74		1	<=W	2	<T	400		1	<=W	5	<T	1	<=W	2	<=W	400		1	<=W	2	<=W	1	<=W	2	<=W
	950801		no data		4	<T	1	<=W	1	<=W	2	<T	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
	950801		no data		4	<T	1	<=W	1	<=W	2	<T	1	<=W	1	<=W	1	<=W	2	<=W	1	<=W	1	<=W	2	<=W	1	<=W	2	<=W
	950801		1	<MD	43		1	<=W	1	<=W	263		1	<=W	1	<=W	1	<=W	11		264		16		14		51		9	
	950801		1	<MD	21		1	<=W	1	<=W	206		1	<=W	1	<=W	1	<=W	11		215		14		13		43		8	
	950801		1	<MD	20		1	<=W	1	<=W	175		1	<=W	1	<=W	1	<=W	9		179		11		10		89		6	
	950811	31 days	1	<MD	21		1	<=W	1	<=W	140		1	<=W	1	<=W	1	<=W	20		180		16		20		17		8	<T
	950811		1	<MD	17		1	<=W	1	<=W	130		1	<=W	1	<=W	1	<=W	8	<T	150		10		4	<T	15		2	<=W
	950811		1	<MD	17		1	<=W	1	<=W	160		1	<=W	1	<=W	1	<=W	20		210		17		24		21		8	<T
	950913	64 days	1	<MD	27		1	<=W	1	<=W	250		1	<=W	1	<=W	1	<=W	20		280		29		20		26		8	<T
	950913		1	<MD	15		1	<=W	1	<=W	110		1	<=W	1	<=W	1	<=W	12	<T	140		10		8	<T	17		4	<T
	950913		1	<MD	37		1	<=W	1	<=W	260		1	<=W	1	<=W	1	<=W	14	<T	240		20		10	<T	22		4	<T
	951016	97 days	1	<MD	35		1	<=W	1	<=W	410		2	<T	1	<=W	1	<=W	24		550		32		20		52		4	<T
	951016		1	<MD	52		1	<=W	1	<=W	570		1	<=W	1	<=W	1	<=W	32		770		66		26		45		4	<T
	951016		1	<MD	54		1	<=W	1	<=W	550		1	<=W	1	<=W	1	<=W	36		760		67		30		52		6	<T
	951114	126 days	1	<MD	47		1	<=W	1	<=W	580		1	<=W	1	<=W	1	<=W	60		930		52		60		100		16	<T
	951114		1	<MD	53		1	<=W	1	<=W	570		1	<=W	1	<=W	1	<=W	30		820		70		18	<T	60		4	<T
	951114		1	<MD	40		1	<=W	1	<=W	520		1	<=W	1	<=W	1	<=W	56		920		77		54		69		12	<T
Occ 003	950712	1 day	1	<MD	1	<=W	1	<=W	1	<=W	4	<T	5	<T	7	<T	1	<=W	4	<T	10		1	<=W	2	<=W	1	<=W	2	<=W
	950712		1	<MD	1	<=W	1	<=W	1	<=W	1	<=W	2	<T	2	<T	1	<=W	4	<T	7	<T	1	<=W	2	<=W	1	<=W	2	<=W
	950712		1	<MD	1	<=W	1	<=W	1	<=W	2	<T	4	<T	8	<T	1	<=W	4	<T	9	<T	1	<=W	2	<=W	1	<=W	2	<=W
	950713	2 days	1	<MD	1	<=W	1	<=W	1	<=W	4	<T	4	<T	4	<T	1	<=W	4	<T	9	<T	1	<=W	2	<=W	1	<=W	2	<=W
	950713		1	<MD	1	<=W	1	<=W	1	<=W	4	<T	4	<T	5	<T	1	<=W	4	<T	12		1	<=W	2	<=W	1	<=W	2	<=W
	950713		1	<MD	1	<=W	1	<=W	1	<=W	5	<T	3	<T	5	<T	1	<=W	4	<T	13		1	<=W	2	<=W	1	<=W	2	<=W
	950714	3 days	1	<MD	2	<T	1	<=W	1	<=W	10		6	<T	12		1	<=W	4	<T	22		1	<=W	2	<=W	1	<=W	2	<=W
	950714		1	<MD	2	<T	1	<=W	1	<=W	8	<T	6	<T	10		1	<=W	6	<T	16		1	<=W	2	<=W	1	<=W	2	<=W
	950714		1	<MD	2	<T	1	<=W	1	<=W	7	<T	4	<T	8	<T	1	<=W	4	<T	16		1	<=W	2	<=W	1	<=W	2	<=W
	950719	8 days	1	<MD	3	<T	1	<=W	1	<=W	15		5	<T	8	<T	1	<=W	4	<T	22		1	<=W	2	<=W	1	<=W	2	<=W
	950719		1	<MD	3	<T	1	<=W	1	<=W	11		3	<T	4	<T	1	<=W	4	<T	16		1	<=W	2	<=W	1	<=W	2	<=W
	950719		1	<MD	2	<T	1	<=W	1	<=W	13		5	<T	7	<T	1	<=W	4	<T	18		1	<=W	2	<=W	1	<=W	2	<=W
	950727	16 days	1	<MD	13		1	<=W	1	<=W	75		54		78		1	<=W	8	<T	140		10		10	<T	3	<T	2	<=W
	950727		1	<MD	7	<T	1	<=W	1	<=W	14		8	<T	7	<T	1	<=W	4	<T	16		3	<T	2	<=W	1	<=W	2	<=W
	950727		1	<MD	15		1	<=W	1	<=W	66		40		57		1	<=W	6	<T	100		3	<T	8	<T	8	<T	2	<=W
	950801	21 days	no data		23		1	<=W	1	<=W	50		12		6	<T	1	<=W	2	<=W	30		1	<=W	2	<=W	1	<=W	2	<=W
	950801		no data		12		1	<=W	1	<=W	32		14		22		1	<=W	2	<=W	38		1	<=W	2	<=W	1	<=W	2	<=W
	950801		no data		40		1	<=W	1	<=W	140		46		60		1	<=W	2	<=W	120		1	<=W	2	<=W	1	<=W	2	<=W
	950811	31 days	1	<MD	9	<T	1	<=W	1	<=W	24		7	<T	7	<T	1	<=W	4	<T	17		1	<=W	2	<=W	1	<=W	2	<=W
	950811		1	<MD	5	<T	1	<=W	1	<=W	11		4	<T	4	<T	1	<=W	4	<T	10		1	<=W	2	<=W	1	<=W	2	<=W
	950811		1	<MD	9	<T	1	<=W	1	<=W	25		10		12		1	<=W	4	<T	21		1	<=W	2	<=W	1	<=W	2	<=W